SURVEY REPORT DELAWARE RIVER WATERSHED

PROGRAM FOR
RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE

OCTOBER, 1950

~~UNITED STATES~~ DEPARTMENT OF AGRICULTURE

DELAWARE RIVER WATERSHED

New York, Pennsylvania, New Jersey, Delaware and Maryland

Program for Runoff and Waterflow Retardation and Soil-Erosion Prevention

Pursuant to the Act Approved June 22, 1936 (49 Stat. 1570) as Amended and Supplemented by the Act Approved August 28, 1937 (50 Stat. 876).

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
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DELAWARE RIVER WATERSHED

DELAWARE, NEW JERSEY, NEW YORK, PENNSYLVANIA

NORTHEAST REGION I
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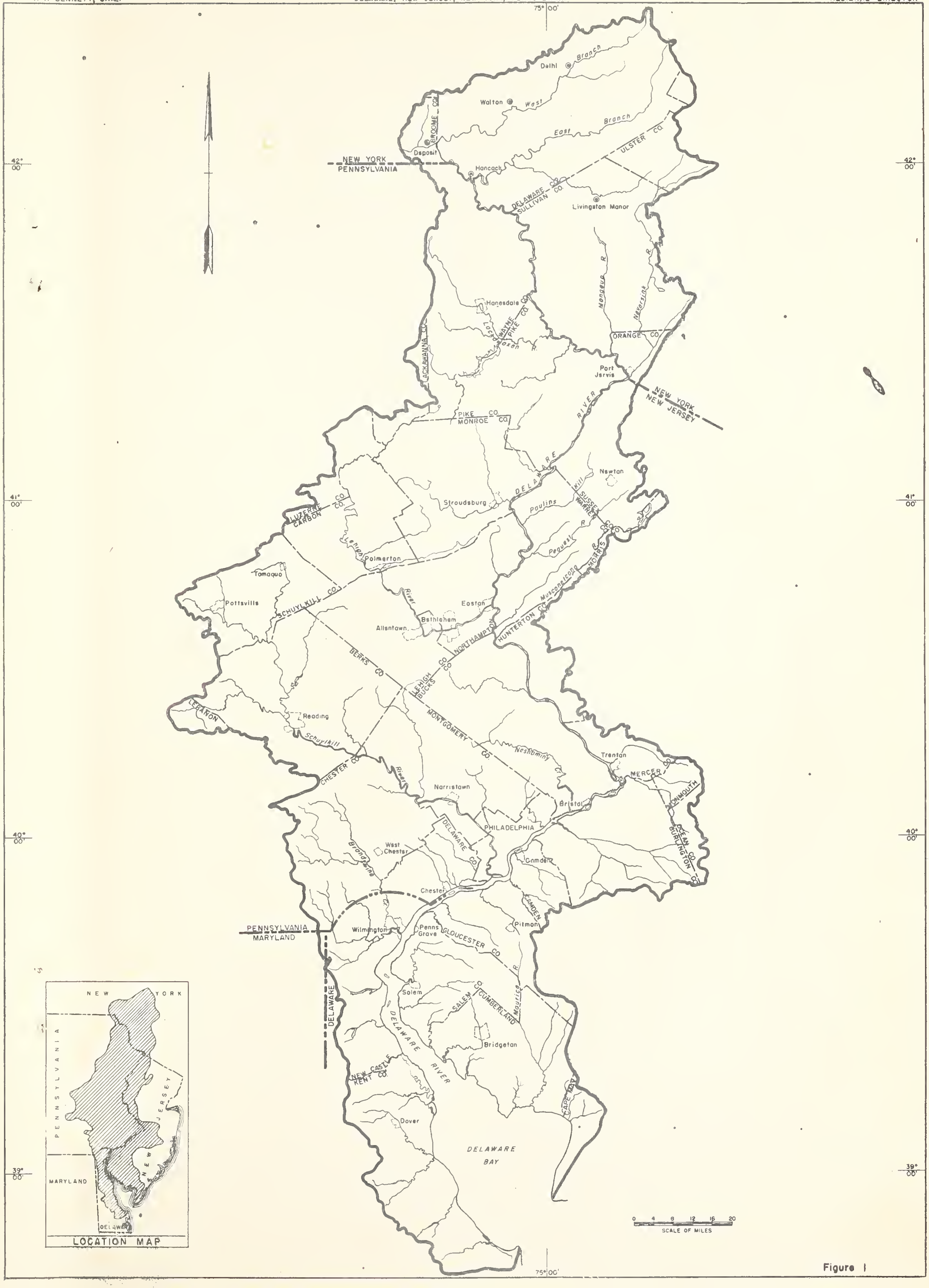

Figure 1

INTRODUCTION

Authority - This report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented by the Act approved August 28, 1937 (50 Stat. 876).

Purpose and Scope of Report - The purpose of this report is to outline a program of runoff and waterflow retardation and soil-erosion prevention for the Delaware River Watershed in New York, Pennsylvania, New Jersey, Delaware, and Maryland; and to present recommendations for installing and maintaining the program, together with an analysis of the costs and benefits.

The Delaware River has a watershed area, excluding Delaware Bay, of 12,765 square miles, of which approximately 18 percent is located in New York, 50 percent in Pennsylvania, 23 percent in New Jersey, 8 percent in Delaware, and 1 percent in Maryland.

RECOMMENDATIONS

It is recommended that a program of runoff and waterflow retardation and soil-erosion prevention be installed in the Delaware River Watershed in New York, Pennsylvania, New Jersey, Delaware and Maryland during a 20-year period at an estimated cost of $37,904,000 to the Federal Government, and at an estimated cost of $39,196,000 or its equivalent 1/ to local interests, making an estimated total cost of $77,100,000 for the installation of the recommended program.

1/ Labor, materials, equipment, land, easements, rights-of-way, and other contributions in lieu of cash payments.

The program will be operated and maintained at an estimated annual cost of $282,000 to the Federal Government, and an estimated annual cost of $7,810,000 or its equivalent to local interests, making an estimated total annual cost of $8,092,000.

It is estimated that the recommended program will yield an average annual benefit of $27,599,040 based on 1949 prices. With prices and costs expected to prevail under intermediate employment levels during the period 1955 to 1965, the ratio of the average annual benefit to the average annual cost is 1.81 to 1.

The program herein recommended includes the intensification, acceleration, and adaptation of certain activities under current programs of the Department of Agriculture, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out this program. The extent to which the work recommended in this program is to be carried out under authority of the Flood Control Act as requested herein or under other authorities will be considered by the Secretary in requesting appropriations for the conduct of the recommended program. Although the current activities of the Department primarily related to the Flood Control Act are not included in the program herein specifically recommended, this program is based on the continuation of such current activities at least at their present level. The extent to which the measures in the recommended program may be carried out by an increase in the current

programs of the Department will be taken into account in requests for the appropriation of funds to carry out the recommended program.

The recommended program, consisting only of measures and practices that contribute directly to substantial and measurable reductions in floodwater and sediment damage, includes certain adjustments in land use in accordance with the needs and capabilities of the land and the following practices and measures: contour strip cropping, cover cropping, diversions and terraces, outlets and waterways, establishing perennial hay, pasture management, contour furrowing, streambank erosion control, erosion control structures, woodland management, tree and shrub planting, land acquisition, stream channel improvement, water retarding structures, and diking.

Technical services and direct assistance will be made available for planning and applying the necessary land use adjustments, for planning and applying conservation measures on the watershed, and for integrating the measures included in the recommended program. Educational assistance, to facilitate the establishment of measures on a subwatershed basis, will be provided as a part of the recommended program.

The Secretary of Agriculture may make such modifications or substitutions of the measures described herein as may be deemed advisable due to changed physical or economic conditions or improved techniques whenever he determines that such action will be in furtherance of the objectives of the recommended program.

The recommended measures will be installed and maintained on a tributary or subwatershed basis under cooperative arrangements with state and local governments, soil conservation districts, or other agencies acceptable to the Secretary of Agriculture.

The authority of the Secretary of Agriculture to prosecute the recommended program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

The Secretary of Agriculture may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

DESCRIPTION OF WATERSHED

The Delaware River rises on the western slopes of the Catskill Mountains in southeastern New York and flows, as the East Branch and the West Branch, in a southwesterly direction to Hancock, New York, where the two branches unite. Thence the river flows in a general southeasterly direction to Port Jervis, New York, forming the boundary between the States of New York and Pennsylvania. From Port Jervis the river flows generally south to Trenton, New Jersey, where it becomes tidal. From Trenton, the Delaware continues, first in a southwesterly direction, past Philadelphia, Pennsylvania, to Wilmington, Delaware, and thence in

a southeasterly direction to Delaware Bay and the Atlantic Ocean. From Port Jervis to near Chester, Pennsylvania, the river forms the boundary between New Jersey and Pennsylvania and from this point to the sea it forms, with the Delaware Bay, the boundary between the States of New Jersey and Delaware. The two major tributaries of the Delaware River are the Lehigh River, with a drainage area of 1,370 square miles, and the Schuylkill River, with a drainage area of 1,910 square miles.

The Delaware River Watershed is approximately 260 miles long from north to south, with a maximum width of 75 miles. The drainage area is 12,765 square miles, of which 2,969 square miles are in New Jersey, 2,362 in New York, 6,422 in Pennsylvania, 1,004 in Delaware, and the remaining 8 are in Maryland. Openland occupies 4,038,200 acres, or 49 percent of the watershed area, while 3,676,500 acres, or 45 percent of the area, is in woodland. The remaining 6 percent is accounted for by roads, urban areas, streams and lakes.

The watershed was divided into three sections on the basis of topography, soils, types of agriculture, land use, and runoff characteristics. The upper part of the watershed is designated as the Upland section and includes 46 percent of the area. It is a hilly and mountainous area with long steep slopes. South of the Upland section is situated the Piedmont section, 31 percent of the area, where slopes are moderate and generally short. This section is intermediate between the Upland and Coastal Plain sections, as regards topography. Portions of the Coastal Plain are essentially

level. The Coastal Plain section represents 23 percent of the watershed.

Annual precipitation, based on 26 to 71-year records, varies from 40 to 50 inches and is well distributed throughout the year. Average annual temperatures vary with elevation and distance from the ocean. The growing season ranges in length from nearly 200 days in the southern portion to approximately 100 days in the high elevations of the headwater areas.

Population of the watershed in 1940 was estimated at 4,700,000. This is concentrated in a number of cities, of which the four largest are Philadelphia, Pennsylvania; Trenton, New Jersey; Camden, New Jersey; and Wilmington, Delaware.

Agriculture is one of the basic industries in the watershed. Dairying, truck farming, and poultry production are major enterprises. The nearness of Philadelphia and New York markets makes agriculture important in the watershed.

The importance of the watershed as a source of water for domestic and industrial purposes has been emphasized by the increased demand for water in New York City and the large metropolitan areas of New Jersey, Pennsylvania, and Delaware.

FLOOD PROBLEMS

Flood damages in the Delaware River Watershed are of frequent occurrence. On some of the small tributaries, losses occur annually. These floods most commonly occur in the spring and early summer and the losses sustained are mainly to pasture and crops. Because

of frequent flooding in some tributaries, the bottomland is used less intensively than its capability would otherwise permit. This type of damage represents an annual loss of potential net income of approximately $240,000.

Much greater amounts of damage accrue from floods of less frequent occurrence. The July 1945 flood was typical of the floods caused by very intense local summer storms which do not usually create flood flows on the main stem or on the larger tributaries. Damages resulting from this flood, on the small tributaries in the vicinity of Easton, Pennsylvania, were in excess of $4,000,000. Other recent floods of this type occurred August 1947 causing approximate damages of $1,000,000 in the Calicoon Creek Watershed and August 1945 causing approximately $120,000 damages in the Chester Creek Watershed. The May 1942 flood is typical of those produced by storms covering thousands of square miles and lasting two or more days. In such a flood large quantities of water are precipitated on the watershed, but rainfall intensities are not necessarily high. Damages caused by this flood were in excess of $12,000,000 on the main stem of the Lehigh River and $6,000,000 on the Lackawaxen River, as reported by the Department of the Army, Corps of Engineers, in House Document No. 587, 79th Congress, 2d Session, and House Document No. 113, 80th Congress, 1st Session. Many more millions of dollars of damages occurred in other parts of the Delaware River Watershed.

Damages caused by sedimentation occur mainly as increased dredging costs of navigable streams and harbors, increased

maintenance costs of highways, and higher water treatment costs. An estimated 2,300,000 cubic yards of eroded sediment are being deposited annually in the Delaware River. The cost of removal of that portion of the sediment which settles in navigable channels amounts to approximately $747,500 per year. Eroded sediments affect highway maintenance costs by deposition in culverts and ditches, and on the highway surface. This impairment of drainage systems frequently results in washouts and other damages to highways. Cultivated farm lands are the major source of sediment. The greatest damage is caused by storms occurring during the early growing season when fields do not have sufficient protective cover. Deposition of sediment in low gradient stream channels and on adjacent bottomlands contributes to increased flood damage and intensifies land drainage problems.

Soil erosion in the Delaware River Watershed, in addition to increasing maintenance costs of transportation systems and intensifying land drainage problems, seriously affects land productivity and crop production costs. Based on the present rate of soil erosion, the annual loss from reduced yields and increased production costs necessary to prevent yield declines is an estimated $2,071,500.

Other damages caused by floods, while not evaluated in monetary terms in this report, include loss of life, illness, insecurity of property and income, disruption of public services, and disturbance of the general economic and social activity of the population.

Average annual damages are shown in table 1. These damages do not include those which will be prevented by current or authorized programs of public agencies.

Table 1. Estimated Average Annual Monetary Damage
Delaware River Watershed
(1949 Prices)

Type of Damage	Average Annual Damage	
	(dollars)	
Damage Due to Inundation		
Agricultural	373,100	
Non-Agricultural	1,279,600	
Subtotal		1,652,700
Damage Due to Sediment		
Harbor and Channel Dredging	747,500	
Highway	135,000	
Water Treatment	15,600	
Subtotal		898,100
Damage Due to Erosion		2,071,500
TOTAL AVERAGE ANNUAL DAMAGE		4,622,300

ACTIVITIES RELATED TO FLOOD CONTROL

The Department of Agriculture through four of its agencies -- Production and Marketing Administration, Forest Service, Extension Service, and the Soil Conservation Service -- is presently engaged in several programs directly associated with floodwater retardation and soil-erosion prevention. An appraisal was made of these programs in the Delaware River Watershed and certain portions were deemed of primary importance to the objectives of the Flood Control Act. It was found that the portions of the programs which involved changes in land use, strip cropping, cover cropping, diversions and terraces, outlets and waterways, establishing perennial hay, pasture improvement and management, contour furrowing, streambank erosion control, erosion control structures, woodland management, tree planting, and protection of woodlands from fire and grazing effect reductions of floodwater and sediment damages.

The Production and Marketing Administration, with its Agricultural Conservation Program of direct aids, offers financial assistance to farmers for the application of many of these practices and measures.

The Forest Service, cooperating with state forestry agencies in farm forestry 1/ and in fire control and planting stock production 2/, is currently assisting states to establish sound forestry practices. The present fire protection is adequate.

1/ Norris-Doxey Act (Cooperative Farm Forestry Act) of May 18, 1937 (50 Stat. 188).

2/ Clark-McNary Act of June 7, 1924 (43 Stat. 653), as amended.

The Department also cooperates with State Extension Services and Experiment Stations in educational and research work in the conservation of soil and water resources.

The Soil Conservation Service is furnishing technical services and incidental informational aids for the planning and installation of soil and water conservation practices and measures in cooperation with soil conservation districts.

The Department of Agriculture is now expending $947,400 annually in the Delaware River Watershed to carry out the portions of these programs which produce flood control and associated benefits.

Proposed for construction by the Department of the Army, Corps of Engineers, are two flood control reservoirs in the Lackawaxen River Watershed, one in the Lehigh River Watershed, and local improvement works on the Lehigh River at Allentown and Bethlehem, Pennsylvania. Local protection works have been installed on the Rancocas Creek at Mt. Holly, New Jersey.

The Commonwealth of Pennsylvania has under construction a channel improvement project on the Schuylkill River above Norristown. This project consists of the removal of culm deposits from the river channel and floodway and the construction of desilting basins. The Department of the Army, Corps of Engineers, is authorized to remove the culm from the Schuylkill River below Norristown, Pennsylvania.

The various states and other local public agencies administer and protect approximately 425,000 acres of forest land in the Delaware River Watershed. In general, this land is managed to provide good watershed protection.

Soil conservation districts, organized under state laws, have been established in 29 of the 43 counties partly or wholly within the watershed. A land use program has been developed by these districts.

The Interstate Commission on the Delaware River Basin, created by joint action of the States of Delaware, Pennsylvania, New Jersey, and New York, is making a study of the water resources of the watershed, which will result in recommendations for the development and conservation of these resources.

Within the watershed are numerous private associations and groups which have been organized to encourage conservation of soil, water, and forest resources and which are directly or indirectly concerned with flood control.

The benefits of the program herein recommended do not include the benefits afforded by these activities.

RECOMMENDED PROGRAM

The recommended program of runoff and waterflow retardation and soil-erosion prevention includes certain land use adjustments in accordance with the needs and capabilities of the land and the following practices and measures:

Contour Strip Cropping

The practice of growing hay or other close growing and soil conserving crops in contour strips, alternating with clean tilled or soil depleting crops, will be applied on approximately 870,000 acres of cropland. Contour tillage operations in conjunction with

contour strip cropping will provide appreciable surface detention storage for runoff. Such a system will, in addition, keep at least half the sloping cropland in erosion resisting crops at all times, lessen the amount and velocity of runoff and the concentration of water in gullies or channels, thereby reducing the losses of soil by erosion.

Cover Cropping

The practice of growing temporary crops to provide vegetative cover on land following the harvesting of clean tilled crops until the next regular crop is planted will be applied on approximately 118,400 acres of cropland. A satisfactory vegetative cover will lessen the impact of rain drops on the soil, thus reducing erosion and maintaining the soil in condition to readily absorb water. The organic matter added to the soil by cover cropping will increase its water holding capacity.

Diversions and Terraces

Approximately 3,040 miles of diversions and terraces will be installed to provide for intercepting surface runoff from sloping land and carry it in properly designed and constructed channels across the slopes to an outlet or waterway. Terraces will be installed on the more moderately sloping lands with short rotations. Diversions will be installed on the steeper slopes and in conjunction with less intensive rotations. The installation of these measures will furnish protection from damaging runoff to the lands lying immediately below and will significantly reduce erosion and sediment production.

Outlets and Waterways

Adequate systems for the disposal of runoff water are a necessary part of the program to reduce floodwater and sediment damage. Approximately 6,480 acres of outlets and waterways will be established to provide for the safe disposal of runoff from terrace and diversion systems. This will result in reduced gully erosion and sediment production. The outlets and waterways will be vegetated and will include broad meadow strips and constructed channels. Supporting structures, required as a part of the disposal system, are described in another paragraph.

Establishing Perennial Hay

Approximately 281,430 acres of perennial grasses and legumes will be established to protect land not suitable for row crops and to protect such measures as diversions, and outlets and waterways. The success of this measure depends on the quality of the stand secured. Proper fertilization, therefore, is a definite part of the measure designed to secure an erosion-resisting crop. This measure, by increasing the infiltration rate, will reduce runoff and flood damage and, by protecting other measures, will reduce gully erosion and the resulting sedimentation.

Pasture Management

Pasture management, consisting of mowing to remove weeds and mature grasses, the scattering of droppings, and the control of grazing intensity, will be applied on approximately 685,900 acres of pasture so that the improved vegetative cover will increase infiltration and reduce runoff. Fences will be used to facilitate the

control of grazing intensity. Brush or other obstructions to mowing will be removed where feasible.

Contour Furrows

Level furrows or small level terraces will be installed on approximately 147,100 acres of pasture land. The furrows will be spaced and constructed so that approximately one-half inch of runoff will be held in detention storage. In addition to reducing runoff, the installation of this measure will control erosion on sediment source areas.

Streambank Erosion Control

Approximately 275 miles of eroding streambanks along minor tributaries will be controlled by the use of riprap and shrub plantings. Livestock will be excluded by either wire or multiflora rose fence. The establishment of this measure will halt the destruction of fertile bottomlands and will reduce the quantity of sediment getting into the streams.

Erosion Control Structures

Approximately 9,800 erosion control structures, including small check dams, gully structures, and culverts, will be installed as part of the water disposal system or for gully stabilization. Concentration of runoff requires special erosion control structures to protect the channels or natural drainageways from gullying and to furnish protection to railroad and highway ditches. New and larger culverts will be necessary to discharge runoff safely under railroad and highway fills. The establishment of this measure will reduce the rate of gully erosion in existing drainageways and permit

the installation of adequate water disposal systems which will materially reduce sheet and gully erosion on the fields protected.

Woodland Management

This measure provides for the intensification of management on all woodlands for the purpose of improving their hydrologic conditions. In the main, this improvement will consist of the development of a better forest floor. Under such conditions, infiltration rates will be greater, detention storage capacity will be increased, and the area of impermeably frozen soil will be reduced during the winter and spring. This will result in reducing the surface runoff and erosion from woodland areas.

Coincidental with hydrologic improvement, increased growth and stocking of woodlands will ultimately provide higher and more sustained income from these lands. Such returns will make it profitable for woodland owners to participate in the program and more than justify the costs involved.

Improved woodland management will be accomplished through an expanded program of technical services. These services will afford help in planning and applying woodland measures, including the preparation of management plans for 3,372,000 acres in private holdings and 168,000 acres to be acquired in public ownership. The plans will outline the steps necessary to operate woodlands efficiently and economically while integrating watershed protection and timber production objectives. Technical service and advice on timber marking will be provided to minimize clear cutting and destructive logging practices in harvest cuttings and to improve timber stands. These steps are

necessary to develop and maintain the healthy soil conditions and vigorous growth needed to realize the objectives of the program. Additional technical service will be required on shallow soil woodland areas where cultural operations are needed to improve stand composition. Here the aim will be the development of thrifty, mixed stands of species whose litter is highly favorable for humus production, thereby contributing maximum quantities of organic matter to the soil as a means of increasing its moisture storage capacity.

Technical advice will be furnished the owners of 3,700,600 acres of woodland on logging methods which cause the least disturbance to woodland soil and drainage ways, including the proper installation and location of logging roads and skid trails. Existing roads and trails are sources of aggravated runoff and sedimentation as a result of poor location and inadequate drainage facilities. Correction of the unsatisfactory conditions resulting from past operations and the prevention of their recurrence in future operations is necessary if other woodland management practices are to be fully effective. This will be accomplished by the installation of water spreading devices, small check dams, gully structures, and culverts. On 276,000 acres of non-commercial woodland where existing roads and trails are sources of runoff and sedimentation, this unsatisfactory condition will be corrected.

Livestock will be excluded from 128,700 acres of present farm woodland area and from 145,000 acres of land to be converted from openland to woodland as a part of woodland management. Grazing reduces the organic matter and compacts the soils of woodlands, thereby

reducing seriously their infiltration and water-holding capacity. Grazing control must be instituted as an essential part of proper woodland management, if the previously mentioned installations and practices are to be effective.

To assure the cooperation of local owners in the installation and maintenance of good woodland management practices, advice and assistance will be given on the utilization and marketing of forest products.

Tree and Shrub Planting

The total woodland area will increase from 3,676,500 acres to 3,976,600 acres by the conversion of 300,100 acres of openland to woodland by natural reseeding or by planting. Tree planting is recommended for the establishment of a soil improvement and watershed protective cover on approximately 232,900 acres of openland which will not restock naturally within a reasonable length of time. Early establishment of a forest cover on these lands will reduce soil movement, increase infiltration rates, and enlarge soil moisture storage capacity. This planting is recommended on approximately 222,900 acres of private land and on about 10,000 acres of land to be acquired by public agencies.

Shrub planting is recommended on about 23,700 acres of field borders. Installation of this practice will provide good land cover in the partially shaded areas adjacent to woodlands and improve infiltration and soil moisture storage capacity, thereby reducing runoff and erosion.

Land Acquisition

Public acquisition is recommended for approximately 167,600 acres of damaged headwaters land. These areas, normally well forested, have so been abused that they constitute critical floodwater sources and need major rehabilitation to restore the watershed cover for effective runoff and sediment control. Because of low productivity and the low returns to be derived from this land for many years, many landowners are not able to manage their land for either watershed protection or timber production. Public acquisition is an essential first step in insuring the establishment of necessary rehabilitational measures and providing continuity of management.

The objectives of the program can be met by acquisition by state or local governments. The land will be acquired through voluntary sales by owners in accordance with existing state policy.

Stream Channel Improvement

Approximately 423 miles of stream channel will be improved to reduce the damages resulting from inundation of valuable bottomland, furnish flood protection for high-value improvements, such as farm buildings, and provide outlets for drainage works. The discharge capacity of stream channels will be increased by the removal of debris and sediment deposits, clearing and snagging, realignment, and bank sloping.

Water Retarding Structures

Approximately 133 upstream floodwater retarding structures will be constructed to reduce inundation damage by providing temporary storage for flood runoff. Drainage areas above the structures will average less than two square miles. The structures will be earth fill dams through which a small, low elevation outlet conduit, uncontrolled by gates or valves, will be constructed to draw down the temporary storage. A spillway adapted to site conditions and meeting required design criteria will be used to provide an outlet for flood flow in excess of the storage capacity provided by the structure.

Diking

Seventeen miles of diking will be constructed to provide protection from inundation to valuable bottomland and to such improvements as highways and farm buildings where limitation of rights-of-ways and gradients prohibits the use of channel improvement. Floodways will be provided to safely carry flood discharges of design frequency.

The quantities of measures included in the recommended program are based on total watershed needs less the estimated accomplishments under "going" programs over a 20-year period. Minor reductions in the acreages of clean tilled and small grain crops and large acreage increases in managed pasture, perennial hay crops, and farm woodlands will result from the installation of the recommended program.

Educational Assistance

Landowners and operators and others in the watershed will be furnished educational assistance relative to the need for the recommended program and its purposes and objectives. Information will be supplied as to the manner in which landowners and operators now obtain services and assistance that are available through the various governmental agencies, and how they can and should, by their own efforts, contribute successfully and most economically to the accomplishment of the overall objectives. Intensified educational efforts will be directed to familiarizing farmers with the specific practices and measures essential to runoff and waterflow retardation and soil-erosion prevention, how to install those measures not requiring the detailed assistance of a specialized technician, how to maintain them, and how to integrate them into the soundest farming system to produce the greatest benefit over a long period of time.

The Department is committed to a watershed and subwatershed approach in carrying out the recommended program. It is essential that educational assistance provided under this program be directed toward furthering the specific objectives of floodwater and sediment damage reduction and that it be fitted as to method and synchronization into subwatershed operations activities.

Technical Services

Technical services will be provided for (1) planning and applying woodland improvement measures and management practices for watershed protection, (2) planning and applying land use adjustments,

(3) planning and applying conservation measures on the farm, and (4) integrating the installation of individual measures into a proper combination to achieve the most effective program of runoff and waterflow retardation and soil-erosion prevention. These services are required to assist the people in the watershed in installing the recommended measures on their land and in adopting the recommended practices for their farm and woodland operations.

Testing the Effectiveness of the Program

The Department of Agriculture will conduct such investigations, design studies, detailed planning for program installations and evaluations of the effects of the recommended measures and practices as may be necessary to adapt them to watershed problems for accomplishing the objectives of the program in an efficient manner.

These investigations will be made on selected subwatersheds to determine the most effective methods for operating and maintaining the recommended measures and practices.

COST OF RECOMMENDED PROGRAM

The estimated cost of installing the recommended program in the Delaware River Watershed is shown in table 2.

The Federal Government will bear approximately 49 percent of the total installation cost, state and local governments approximately 12 percent, and private interests approximately 39 percent.

Table 2. Estimated Cost of Installing the Recommended Program
Delaware River Watershed
(1949 Prices)

Measure	Unit	Quantity	Total Cost (dollars)
1. Contour Strip Cropping	Acres	870,000	4,343,000
2. Cover Cropping	"	118,400	1,657,000
3. Diversions and Terraces	Miles	3,040	1,278,000
4. Outlets and Waterways	Acres	6,480	3,031,000
5. Establishing Perennial Hay	"	281,430	13,492,000
6. Pasture Management	"	685,900	9,036,000
7. Contour Furrowing	"	147,100	2,256,000
8. Streambank Erosion Control	Miles	275	4,158,000
9. Erosion Control Structures	No.	9,800	5,002,000
10. Woodland Management	Acres	3,976,600	20,044,000
11. Tree and Shrub Planting	"	256,600	6,912,000
12. Land Acquisition	"	167,600	1,642,000
13. Stream Channel Improvement	Miles	423	2,824,000
14. Water Retarding Structures	No.	133	1,343,000
15. Diking	Miles	17	82,000
TOTAL			77,100,000

The costs of testing effectiveness of program, administration of direct aids, technical services, and educational assistance are included in the above costs. The estimated costs for technical services and educational assistance amount to approximately 18.1 percent and 3.4 percent respectively of the installation cost of

the recommended program. Of these amounts, non-federal public agencies will bear one-half the cost of technical services on privately owned woodland and one-half the cost of educational assistance. The estimate includes about 1.0 percent of the total cost for testing the effectiveness of the program and 2.7 percent for the administration of direct aids.

The estimated average annual cost of operating and maintaining the recommended program is $8,092,000. The Federal Government will bear approximately 3.5 percent of this annual maintenance cost to provide technical services necessary to assure proper use and conservation and management of lands. State and local governments will bear approximately 4.9 percent of this cost, and private interests will bear the remaining 91.6 percent.

BENEFIT FROM RECOMMENDED PROGRAM

The estimated average annual monetary benefit resulting from the recommended program when it attains maximum effectiveness is shown in table 3.

In addition to the benefits listed in table 3, there are many unevaluated benefits, such as saving of life and alleviating mental distress, improving community organizations and facilities, maintaining and increasing the tax base, improving recreational opportunities, and increasing fish and game production.

Table 3. Estimated Average Annual Monetary Benefit
from the Recommended Program
Delaware River Watershed
(1949 Prices)

Type of Benefit	Average Annual Benefit	
	(dollars)	
Reduction in Damage Due to Inundation		
Agricultural	179,840	
Non-Agricultural	616,600	
Subtotal		796,440
Reduction in Damage Due to Sediment		
Harbor and Channel Dredging	448,500	
Highways	108,000	
Water Treatment	10,900	
Subtotal		567,400
Reduction in Damage Due to Erosion		1,581,700
Land Enhancement		240,000
Other Benefits 1/		
Increased Crop Production	9,369,100	
Increased Pasture Production	3,268,100	
Increased Woodland Production	10,942,000	
Savings in Production Costs	834,300	
Subtotal		24,413,500
TOTAL		27,599,040

1/ Benefits which accrue to the owners and operators of the land on which the recommended program is installed.

COMPARISON OF BENEFIT AND COST

Based on prices and costs expected to prevail under intermediate employment levels during the period 1955 to 1965, the ratio of the average annual benefit to the average annual cost of the recommended program is 1.8 to 1.

SURVEY REPORT
DELAWARE RIVER WATERSHED

(APPENDIXES)

PROGRAM FOR
RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE

OCTOBER, 1950

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIXES
SURVEY REPORT

DELAWARE RIVER WATERSHED

New York, Pennsylvania, New Jersey, Delaware and Maryland

Program for Runoff and Waterflow Retardation and
Soil-Erosion Prevention

Pursuant to The Act Approved June 22, 1936 (49 Stat. 1570)
as Amended and Supplemented by The Act Approved
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Location and Size

The Delaware River Watershed extends from south central New York State to southern Delaware and New Jersey. It is approximately 260 miles long with a maximum width of about 75 miles. Headwaters of the Delaware are on the western slopes of the Catskill Mountains, where the East and West Branches of the Delaware River rise. These two streams unite to form the Delaware at Hancock, New York, at which point the drainage area is 1,515 square miles.

The West Branch of the Delaware and the Delaware River proper form the state boundary between New York and Pennsylvania for a distance of 90 miles, ending at Port Jervis, New York. South from Port Jervis the river is the boundary between Pennsylvania and Delaware to the west, and New Jersey to the east.

The total area of the watershed, excluding the area of Delaware Bay, is 12,765 square miles. Of this total, 2,362 square miles are in New York State, 2,969 in New Jersey, 6,422 in Pennsylvania, 1,004 in Delaware, and the remaining 8 are in Maryland.

Principal tributaries of the Delaware, with their drainage areas and locations by states, are listed in table 1. Figure 1 shows the political subdivisions and drainage pattern of the Delaware River Watershed. The river is tidal below Trenton, New Jersey, 283 miles downstream from the headwaters. The drainage area above Trenton is 6,796 square miles. Total stream fall from source to tidewater is more than 3,200 feet.

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DELAWARE RIVER WATERSHED
DELAWARE, NEW JERSEY, NEW YORK, PENNSYLVANIA

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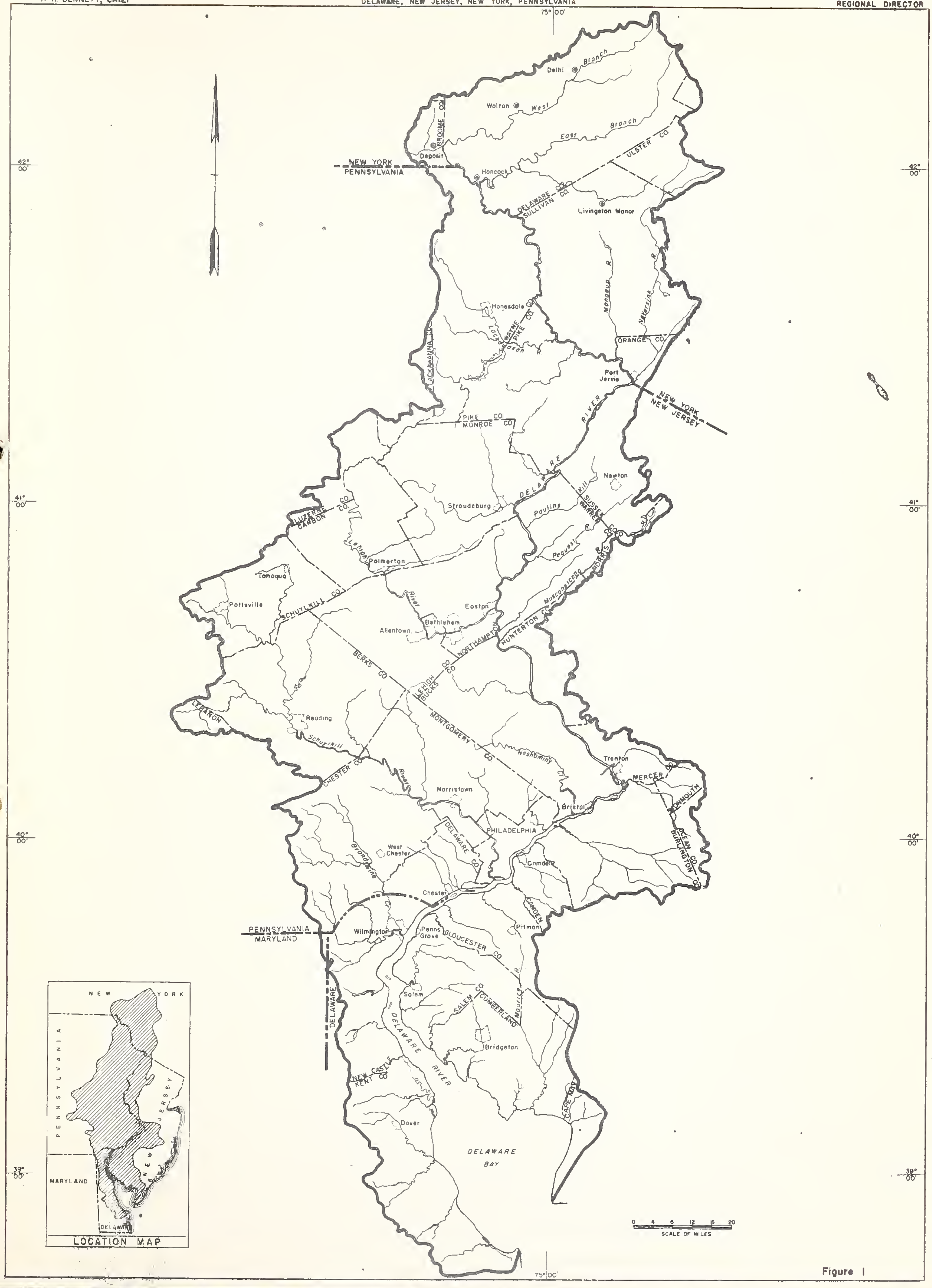

Figure 1

Table 1. Principal Tributaries of the Delaware River

State	Name of Tributary	Drainage Area of Tributary (square miles)
New York	West Branch Delaware River	675
	East Branch Delaware River	840
	Mongaup River	211
	Neversink River	346
	Callicoon Creek	111
Pennsylvania	Equinunk Creek	56
	Brodheads Creek	285
	Lackawaxen River	583
	Bushkill Creek - Stroudsburg, Pa.	149
	Bushkill Creek - Easton, Pa.	70
	Lehigh River	1,370
	Neshaminy Creek	233
	Schuylkill River	1,910
	Chester Creek	66
	Brandywine Creek	333
	Tohickon Creek	97
New Jersey	Paulins Kill	176
	Pequest River	150
	Musconetcong River	254
	Assunpink River	90
	Rancocas Creek	352
	Salem River	112
	Maurice River	388
Delaware	Christina River	573 1/

1/ Includes Brandywine Creek.

Physical Divisions of the Watershed

The watershed was divided into three sections for the purposes of this survey as shown in figure 2. These sections were designated as Upland, Piedmont and Coastal Plain, and they occupy, respectively, 46, 31, and 23 percent of the total drainage area. They reflect general topographic, soil and land use conditions, and types of agriculture.

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PHYSICAL SUB-DIVISIONS
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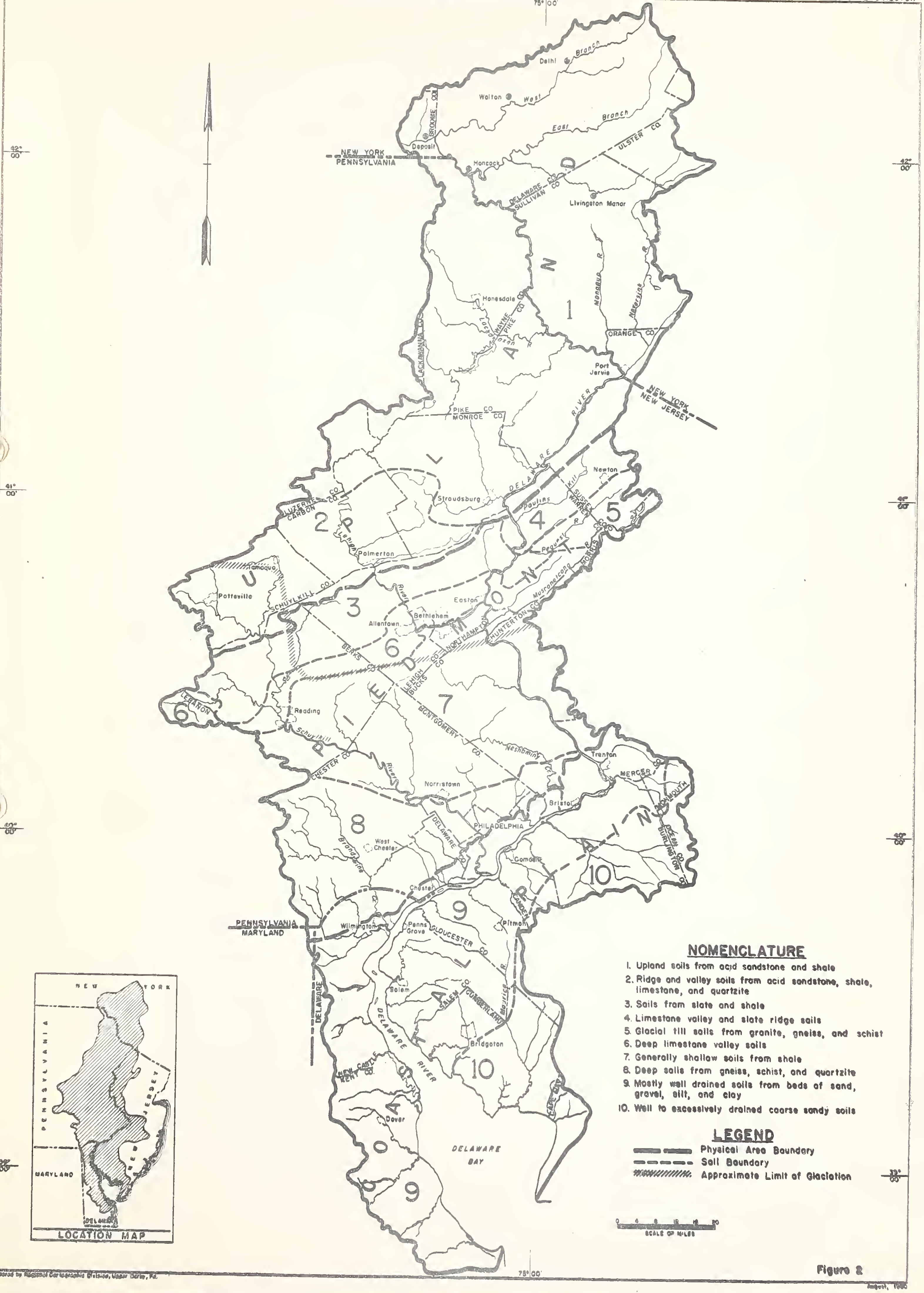

Figure 2

The Upland section is the upper part of the watershed north of and including the Appalachian Mountain Front. It embraces parts of two counties in New Jersey, parts or all of seven in Pennsylvania, and all of the New York State portion of the watershed. It has generally rugged topography with long steep slopes.

Rolling to hilly topography prevails in a large portion of the Piedmont section. Slopes are generally shorter than in the Upland section; in the limestone portion of the section drainage patterns are often indistinct due to sinks. Topography becomes very gentle in the Coastal Plain section.

Soils

Soils were assigned to one of 10 groups, classified on the basis of manner of formation, bed rock, and texture. The locations of the soil groups are shown in figure 2, with a key explaining generalized characteristics of the groups.

The soils in the northern part of the watershed are derived from glacial till and outwash material largely from the local acid sandstones and shale, but with some admixture of crystalline rock. Much of the upland is poorly or imperfectly drained and has low infiltration rates. The steeper slopes usually have well drained but shallow soils. Nearly all of the glaciated areas are gravelly or flaggy and the steep slopes are frequently stony. A limited area of glaciated limestone soils occurs in Carbon, Schuylkill and southern Monroe Counties in Pennsylvania. Most of this area is well drained but some hardpan

and permanently wet soils are included. Other limestone areas occur in the Piedmont section under soil groups 3 and 4. Some effects of glaciation are shown in the eastern portion; the remainder is residual in character. These areas are well drained, have gentle slopes, and have experienced moderately severe erosion.

The unglaciated part of the watershed is about half Piedmont Plateau and half Coastal Plain. The soils of the Piedmont include moderately deep to shallow series with low infiltration rates, developed on shale and sandstone, and deep soils with higher infiltration rates developed on schist, gneiss, and quartzite. In the Coastal Plain area the soils nearest the Piedmont Plateau are mostly well drained but include small areas with slowly permeable subsoil and retarded drainage. Farther east and south the soils are sandy, well to excessively drained, and droughty. Soil textures in the Upland and Piedmont sections are classed as heavy, ranging from loams to clay loams. Both limestone and coastal plain soils have low stone contents.

Economy

Several areas of industrial and commercial importance are located in the Delaware River Watershed. These are situated largely in the southern half of the basin.

Ocean traffic utilizing the deep water river channel maintained from Delaware Bay upstream to Philadelphia makes this an important seaport though located many miles from the ocean. Few watersheds of equal size have such a high and diversified industrial production. The manufacture of steel and cement and the

mining of anthracite coal rank high among the many activities. Overland transportation needs are served by an intricate network of railroads and highways.

Population of the watershed (1940 census) is 4,700,000 of which more than half live in urban communities of 10,000 or more. Greatest concentration is in the four largest cities, Philadelphia, Trenton, Camden, and Wilmington, all located along the lower course of the river. The combined population of these four cities is considerably more than 2,000,000. Large sections of the upper watershed are given over almost entirely to recreational and sports activities.

Land Use

Openland

The industrial importance of areas within the watershed tends to obscure the significance of agriculture. Crop and livestock production are important throughout the watershed. Where dairying predominates in the Upland portion, crop rotations from an erosion control standpoint are generally satisfactory. Agricultural production in the Piedmont section is diversified. Corn, wheat and winter barley are staple crops throughout the Piedmont. There is specialization in potatoes in Lehigh and Northampton Counties, Pennsylvania, and many local areas produce peas and tomatoes for canning factories. Crop rotations in those areas need improvement.

There are a few large orchard holdings in Lehigh County, Pennsylvania, and in the southern portions of New Jersey and

Delaware. The Coastal Plain section is, in general, a vegetable crop producing area. There are centers of intensive poultry production in New Jersey and Delaware. Where soils are unsuited to vegetable production, corn and winter grains predominate, and development and use of pastures on the heavier soils is increasing. Improvement of soil by cover cropping and by use of more satisfactory crop rotations is needed in those areas.

The number of farms in the watershed is estimated at 48,300, on the basis of the 1945 Agricultural Census. Openland comprises 49 percent of the watershed area. Of the openland areas land devoted to crops and to pasture accounts for 47 and 21 percent, respectively. Miscellaneous open areas, idle and abandoned farm land, and areas held for real estate development, represent the balance of the openland. There has been considerable abandonment of farm land in the Upland section.

Woodland

The present woodland area covers approximately 3,676,500 acres or 45 percent of the total watershed area. Of this woodland area, 23 percent is in farm woodlots, 65 percent is in privately owned non-farm woods, and 12 percent is in public ownership.

A large portion of the wooded area is in young age classes, and as a whole the stands are greatly understocked. Seedling and sapling, and very poorly stocked stands make up 47 percent of the woodland area. Pole sized stands comprise 35 percent and saw timber stands 18 percent of the area. To a considerable extent the older stands are understocked with trees of good species and form.

Approximately 178,000 acres, or 21 percent of the farm woodlot area, are grazed. In grazed woodland, both timber production and watershed protection values are materially reduced.

The forests in the watershed are diversified in nature and composition because of the range in climate, topography, and soils. They range from spruce types on podzol soils in the Upland area of the northern headwaters region to loblolly pine stands on Coastal Plain sands in lower Delaware. Northern hardwood and oak types are the principal components of the forest over the greater part of the watershed. They comprise 66 percent of the wooded area. Mixtures of hardwoods and conifers make up 28 percent and conifer types account for the remaining 6 percent. As a result of repeated heavy cuttings and devastating fires, extensive areas of scrub oak have become established throughout the anthracite region of Pennsylvania and in sections of New Jersey. In the anthracite coal region many areas have been denuded by strip mining operations and need to be reforested.

By 1910 most of the forest area of the watershed had been cut over for lumber and other forest products. In general, the forests were clear-cut, and in areas contiguous to the coal fields or within reach of other markets for small size timber, repeated cuttings of immature stands have been made. Fires frequently followed the cuttings, completely eliminating reproduction of desirable species.

Forest products play an important role in the economy of many sections of the watershed. Numerous wood-using industries of all types draw upon the wooded areas for all or part of their primary materials. These woodlands are producing at only a

fraction of their potential capacity. The needs of the watershed for wood necessitate importation of both raw materials and finished products. With 45 percent of the watershed in forest land, the potential productivity of this area is sufficient to meet a much greater portion of the local needs for wood products.

Among the more important uses for wood products are lumber, mine timbers, pulpwood and fuelwood. Those uses account for approximately 90 percent of the total annual drain. The remaining 10 percent is used in other miscellaneous products such as posts, cooperage, baskets, poles, piling, and others.

Another function of forest lands is that of watershed protection. New York City and many other large municipalities draw upon the basin for part or all of their water supply. The demands of industry for a year-round supply of clean water are tremendous, and constantly growing. Many of the industries and municipalities are so situated that they are susceptible to heavy damages from floods. Forests are the most common cover in the headwater areas and on the steeper slopes where the water problems begin. Because of the relatively poor condition of much of this forest cover, the problems of low water flows, sedimentation, and flood damages have been intensified.

Present land use in the watershed is shown in table 2.

Table 2. Present Land Use

Delaware River Watershed

Land Use	Area in Acres		Percent of Total Area	
Openland	4,038,200		49.4	
Cropland		1,908,800		23.4
Pasture		850,800		10.4
Abandoned, Idle, & Miscellaneous		1,278,600		15.6
Woodland	3,676,500		45.0	
Grazed		178,000		2.2
Ungrazed		3,498,500		42.8
Roads, Urban, Water, Etc.	454,900	454,900	5.6	5.6
TOTAL	8,169,600	8,169,600	100.0	100.0

Climate

The Delaware River Watershed is subjected to the vagaries of climate associated with areas on and near the northern portion of the Atlantic Coast. The Upland area of the watershed, including portions of the Catskill and Pocono Mountains with summits up

to 3,900 feet above sea level, experiences the cool summers and cold winters associated with high elevations in the Northeast. The lower portion of the watershed, described geologically as Coastal Plain, surrounds Delaware Bay and is close to Chesapeake Bay and the Atlantic Ocean. These bodies of water exert a considerable moderating influence over the low elevation Coastal Plain, which rarely exceeds 300 feet elevation.

The central area of the watershed, or Piedmont section, partakes of features of both the continental type climate of the Uplands and the more marine type found in the lower river basin. In both the Upland and in the topographically rugged Piedmont, climate is closely associated with elevation.

The Delaware River Watershed is in the path of many of the cyclonic disturbances that cross the continental United States from west to east with the interaction of air masses. Precipitation associated with such frontal disturbances may reach flood proportions from more than one type of air mass relationship. Precipitation of moderate intensity, but covering thousands of square miles, is associated with a warm front. When such a front moves slowly, or remains virtually stationary over the watershed, the moderate intensity rainfall may continue for a period of days while warm, moist air is forced to rise over a wedge of colder air until it loses its moisture in the form of rain. Basin-wide floods are invariably associated with such stagnant, warm front rains.

The passage of a cold front across the watershed is likely to generate thunderstorm conditions at a number of points along the front. The intensity of a thunderstorm is related to the severity of the reaction between the advancing mass of cold air and the nearly stationary mass of warm air containing large quantities of precipitable moisture. If the reaction is strong, rainfall intensities will reach several inches per hour but the storm duration will be but a few hours at most. The area covered by a single important thunderstorm may be less than 100 square miles but within that area the high intensity precipitation (both rain and hail) may produce high streamflow and flooding on the smaller watersheds far in excess of that from a warm front storm, the greatest damage from which will be found downstream where the flow from several watersheds has combined. While the individual thunderstorm covers but a very small part of the Delaware Watershed, the passage of a cold front may generate a series of storms within a short time. Such a series of thunderstorms may produce serious flood conditions over more than one smaller watershed, giving rise to high upstream damages. Such storms have a high probability of occurrence during the growing season when crop damage is most severe.

A relatively rare type of storm in the Delaware basin is the tropical hurricane. These rotational storms of high wind velocity accompanied by high rainfall intensity, which originate in the southwestern Atlantic, only occasionally strike the coast as far

north as Cape May, and on moving over land rapidly lose their intensity. Such storms, known only during the warmer portion of the year, have occasionally produced severe flooding on the lower tributaries of the Delaware.

The paths of most storms cross the Delaware Watershed from west to east, moving across the general trend of streamflow. The watershed characteristic tending to produce the severest type of flood peak--orientation so that storm path and streamflow coincide--is luckily found neither on the main stem nor on any important tributary of the Delaware River.

Precipitation

Rain - A map of average annual rainfall shows remarkably little variation from one end of the Delaware Valley to the other. In general, values are above 40 inches per year, with averages at or near the highest elevations approaching 50 inches. This precipitation is distributed through an average year with low seasonal variation, no month showing as little as two inches nor as much as five inches for an average monthly total. (See figures 3 and 4). Few watersheds of equal size exhibit so consistent a rainfall regime. It should not be assumed, however, that this is an area where drought is unknown and rainfall is never excessive. Flood storms frequently precipitate more than a month's normal rain and have been known to produce several times that quantity.

Snow - Much more variation is found when considering precipitation that falls as snow. Large variation is found from year to year, but the northern and highland areas exhibit consistently

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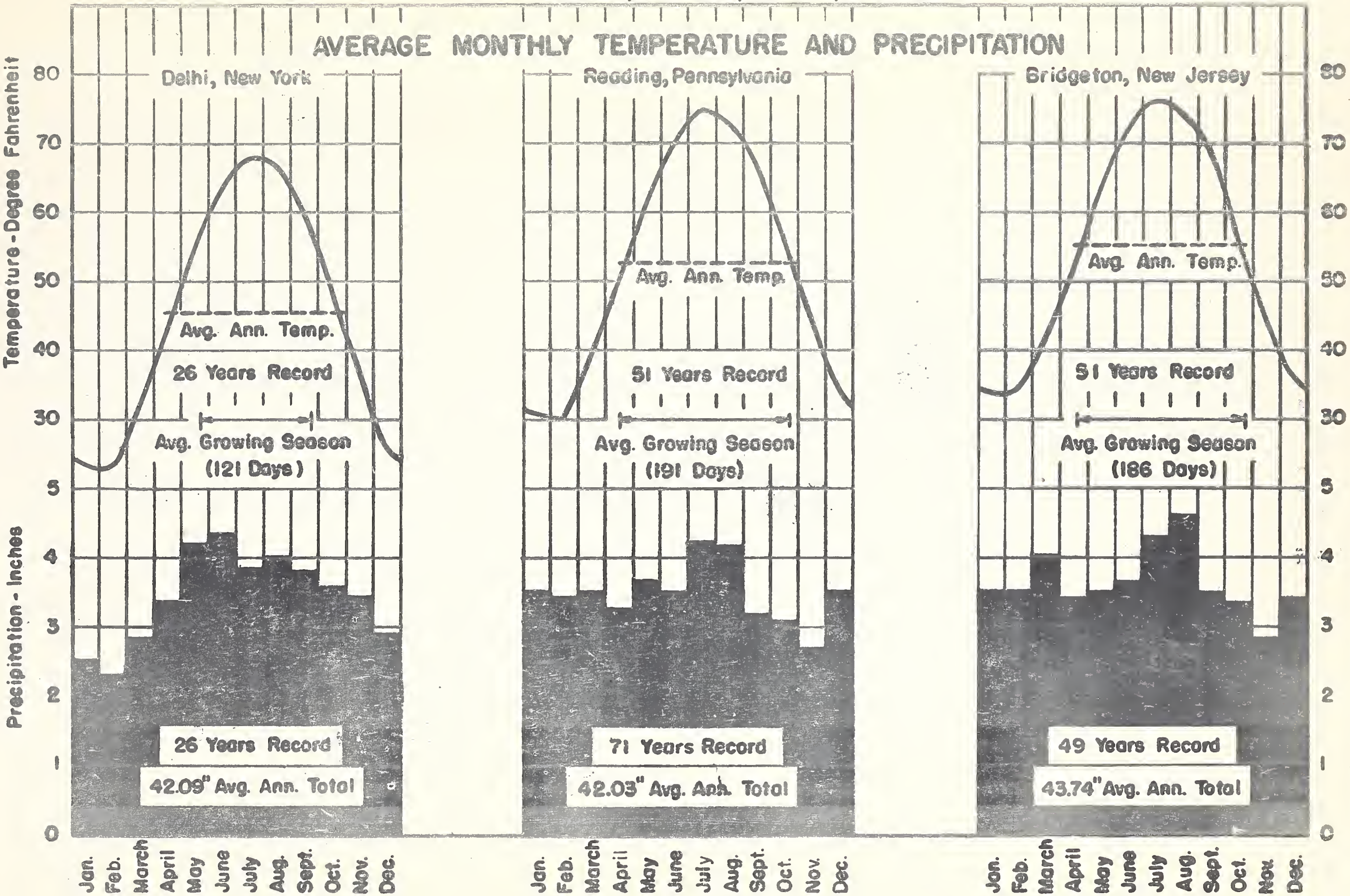

Figure 3

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HYDROLOGIC STATIONS
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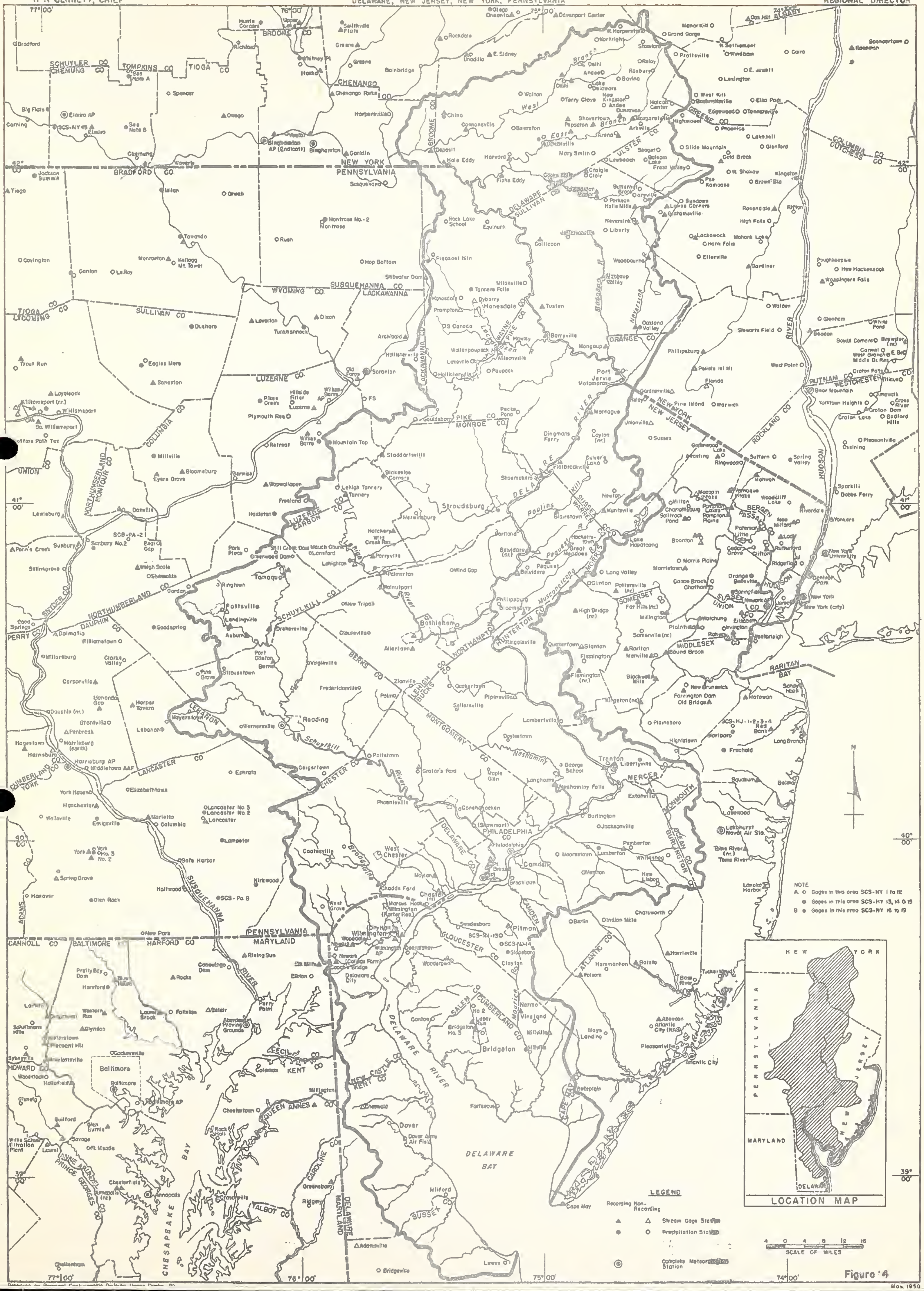

Figure 4

higher average annual snow falls than lower areas near tide water.

Snow is an important contributor to flood producing conditions only where rapid melting of large amounts accompanies excessive rainfall. Spring snow melt has contributed to flood flows on the Delaware Watershed, but its contribution has not constituted an important portion of damaging flood flows.

Frost Penetration - The depth to which frost penetrates the soil varies considerably from year to year, from area to area within the watershed, and from one vicinity to another within a general area. Local variations are closely associated with soil and moisture conditions and most particularly the type and condition of the vegetative cover.

Ground frost increases the flood hazard, particularly when it is of the concrete frost type, which markedly reduces the infiltration potential. The likelihood for the formation of concrete frost is reduced as conservation measures and cover conversions are introduced. The conservation measures proposed in this program will tend to reduce the formation of concrete frost and to maintain or in some cases to actually increase the infiltration rates. While no direct account of this reduction in flood potentiality is taken in this report, there is a very real change favoring increased winter infiltration and reducing the flood potential.

Flood Producing Conditions

There is very little level land in the upper watershed, except in the main valleys. A shortage of land suitable for crop and pasture has lead to over-grazing of steep pasture and hay lands. Woodlands occupy a major portion of the area in the head-water region, and because of their location and poor condition contribute materially to runoff and erosion. Destructive logging methods, severe fires and extensive grazing of farm woodland have left the stands in a poorly stocked condition and have caused a reduction in depth and absorptive qualities of the forest floor. Many areas have shallow or imperfectly and poorly drained soils, and the combination of steep slopes, inadequate land cover, low soil moisture capacity due to poor drainage or thin profile, plus steep stream gradients, leads to frequent severe local flooding. The tributary streams move heavy loads of gravel of varying size and drop the material on flood plains or in channels of more gen-tle gradient streams.

In the Piedmont section, stream valleys are generally wide and gradients less steep. There is considerable ponding of water in sluggishly flowing streams in the glaciated portion of the Piedmont. Land erosion is serious in the Piedmont section and has clogged many stream channels and reduced capacities of the streams to carry flood flows. Rolling to steep topography with long slopes, and off-contour cropping of the land, have combined to accentuate the flood and sediment problems in many parts of the Piedmont.

There is a high potential runoff from areas of bare banks resulting from strip mining of coal. [illegible]

Glacial hardpans or slowly permeable layers at shallow depths in the soils of the upper watershed reduce the moisture holding potential and promote rapid surface runoff. In the New Jersey Coastal Plain area the development of an impervious layer just below plow depth greatly reduces infiltration of water into cropped soils and causes high runoff. The low stream gradients in the Coastal Plain section do not permit rapid disposal of the flood runoff.

Local flooding often results from back water inundation where the flow of water is impeded by ice jams or gorges which form at bridges or at other restrictions. Such flooding occurs following cold winters and the formation of ice of great thickness, when the breakup is rapid and large sections of the ice in a stream move simultaneously. The highest flood of record at Port Jervis was due in part to backwater caused by an ice jam. Local channel improvements at that point have largely eliminated the danger of future floods from that source.

Many flood stage occurrences, especially in village and urban areas, are partially caused by stream channel restrictions such as low capacity bridges, enclosure of the channel itself, and overhanging buildings. Between periods of high stream flows, trash and vegetation accumulate in and near the stream channel. This debris is carried downstream during high flows and lodges against the channel restrictions thus raising water stages to flood damaging proportions.

II. FLOOD, SEDIMENT AND EROSION DAMAGE

Flood Damage

Flood damages in the Delaware River Watershed are of frequent occurrence. On some of the tributaries losses occur annually. These floods most commonly occur in the spring and early summer and the losses sustained are mainly to growing crops and pasture. Annual floods inundate approximately 52,600 acres of openland, of which about 7,300 acres are cropland, 11,600 acres are pasture, and the remaining 33,700 acres are waste or idle. Because of frequent flooding in some tributaries, such as the Pequest River and other low gradient streams, the bottomland is used less intensively than its capability would otherwise permit. Therefore, the direct losses from inundation are relatively less severe. The smaller land returns, resulting from the low intensity use, are not included in the estimate of flood damages. However, where improvements are recommended that will reduce the frequency of inundation to a point which will permit more intensive land use, the benefit is included as land enhancement.

Much greater amounts of damage accrue from floods of less frequent occurrence. The July 1945 flood, occurring on tributaries in the vicinity of Easton, Pennsylvania, was typical of the floods caused by very intense local summer storms which do not usually create floods on the main stem of the Delaware River or the large tributaries. Damages primarily to urban and industrial properties, resulting from this flood, were very severe in Aquashicola, Catasauqua, Hokendauqua, Monocacy, Bushkill, and Lopatcong Creeks.

The recurrence of this flood would cause damages estimated to exceed $4,000,000. Other floods of recent years, similar in type and magnitude, occurred in 1945 on Chester Creek in Pennsylvania, and 1947 on Callicoon Creek in New York.

One of the more recent examples of a serious flood, affecting principally the large tributaries, occurred May 23, 1942. Damages were very severe on the Lehigh, Schuylkill, Brandywine, Lackawaxen, and other streams in the Delaware River Watershed. On the Lehigh and Lackawaxen Rivers, the damages, in terms of 1949 prices, were approximately $18,845,000 and $9,905,000 respectively.1/ Most of these losses occurred to industrial, commercial, residential, and other urban properties.

Studies of information available from federal, state, and local agencies and reconnaissance field investigations were made to determine on which streams damages were significant and to what extent they had been appraised. Average annual damage on the Lehigh River upstream to White Haven, the Schuylkill River upstream to Reading, and the Lackawaxen River were obtained from the District Engineer, Corps of Engineers, Department of the Army, Philadelphia, Pennsylvania. Flood damages on the Delaware River below the confluence of the East and West Branches and on those reaches of streams influenced by tidal action were not evaluated.

1/ Damages on the Lehigh River were reported as $11,800,000 by Department of the Army, Corps of Engineers, in "Review Report on Lehigh River, Pennsylvania", published as House Document No. 587, 79th Congress, 2d Session. Reported by the same Departmental source, and published in House Document No. 113, 80th Congress, 1st Session, the damages on the Lackawaxen River were $6,202,500. These values, when adjusted in accordance with 1949 cost levels, as indicated by the "Engineering News-Record" construction cost index, are shown above.

Damage surveys were made by stream reaches in each major tributary where flood losses were significant. Damages on the small tributaries were determined from studies of representative sample streams. In selecting the sample tributaries to be studied all of the small streams having drainages up to approximately 20 square miles were classified by their pertinent major physical characteristics, such as size of drainage area, stream gradient, extent of natural or artificial storage, and the existence of damageable property. For the Delaware River Watershed in the Piedmont, 27 sample watersheds, totaling 121.1 square miles, were selected. In the Upland portion of the watershed, 37 sample watersheds, totaling 289.5 square miles, were selected.

Average Annual Flood Damages

Flood damages were expressed in terms of average annual values by relating the amount of damages caused by several floods differing in magnitude with their probable chance of occurrence. In order to determine this relationship, in each tributary investigated, damages were appraised by flood stages; flood stages were related to peak discharge, and peak discharge related to probable chance of occurrence. Figures, 5, 6, 7, and 8 illustrate these relationships for Mauch Chunk Creek. The amount of damage associated with different flood stages was determined by estimating depth of inundation of the properties damaged and from owners' accounts of experienced damage. Peak flows related to flood stage were determined by the "Slope-Area" method. The probable chance of occurrence of peak discharges was

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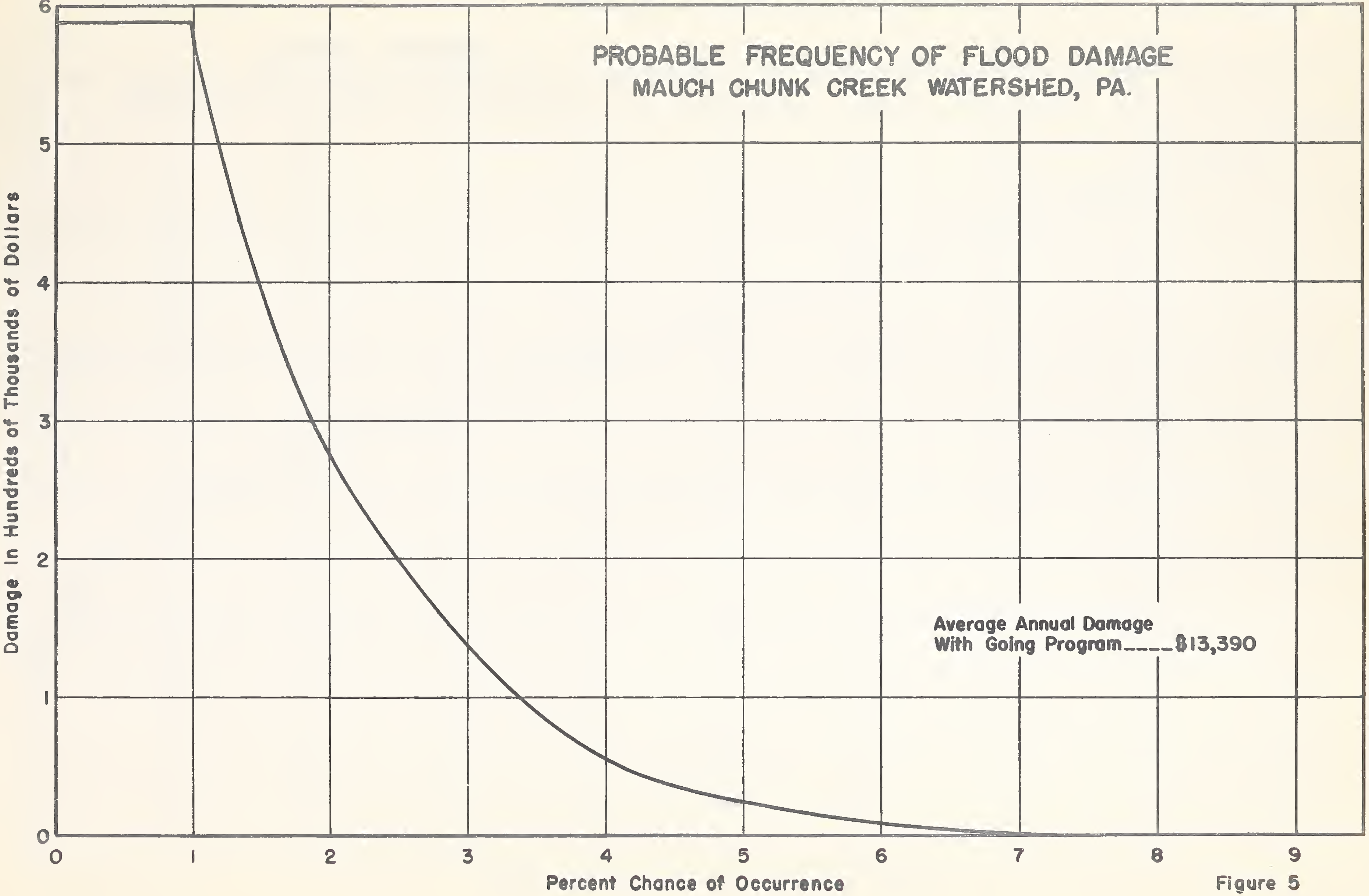

Figure 5

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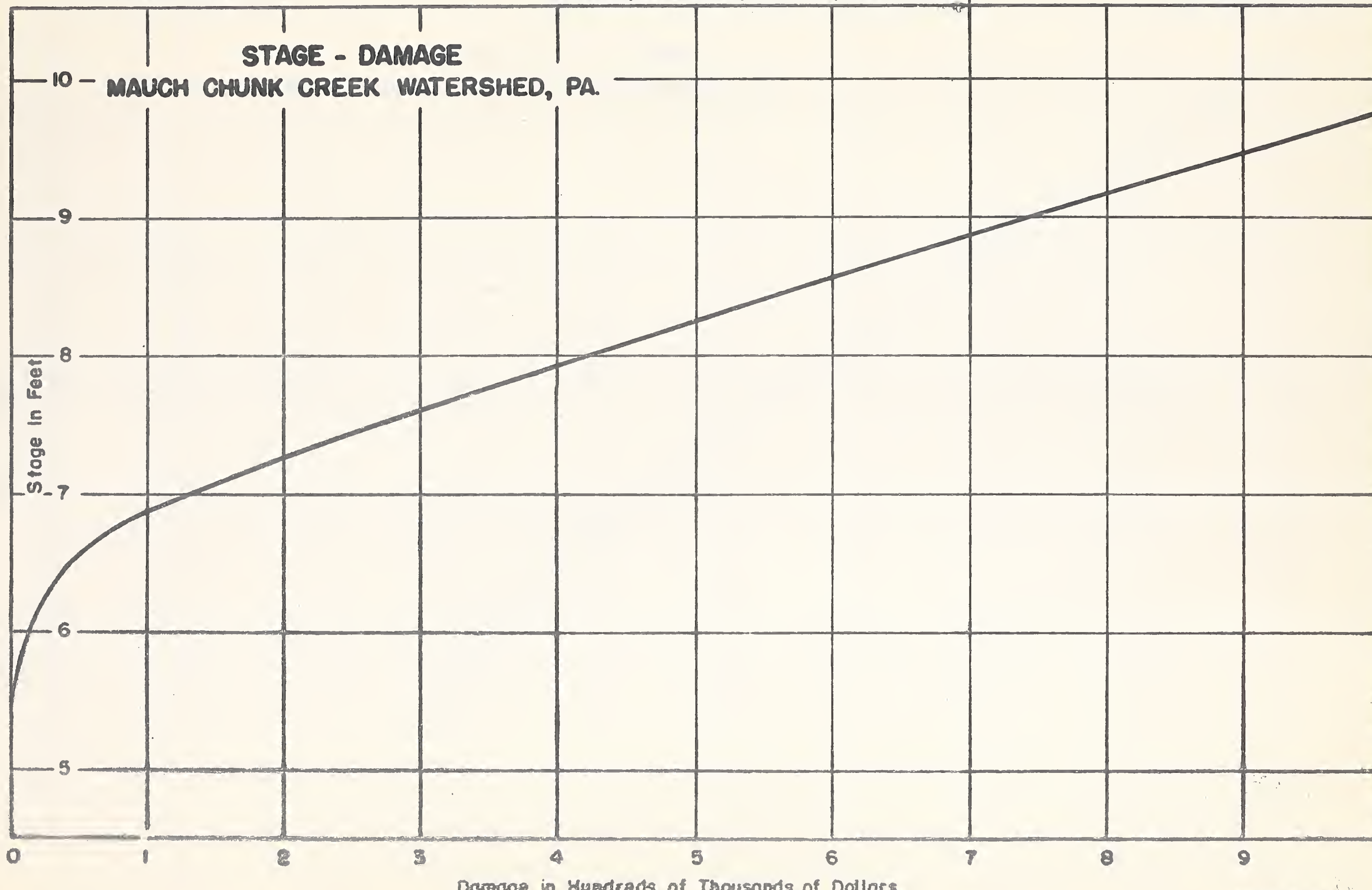

Figure 6

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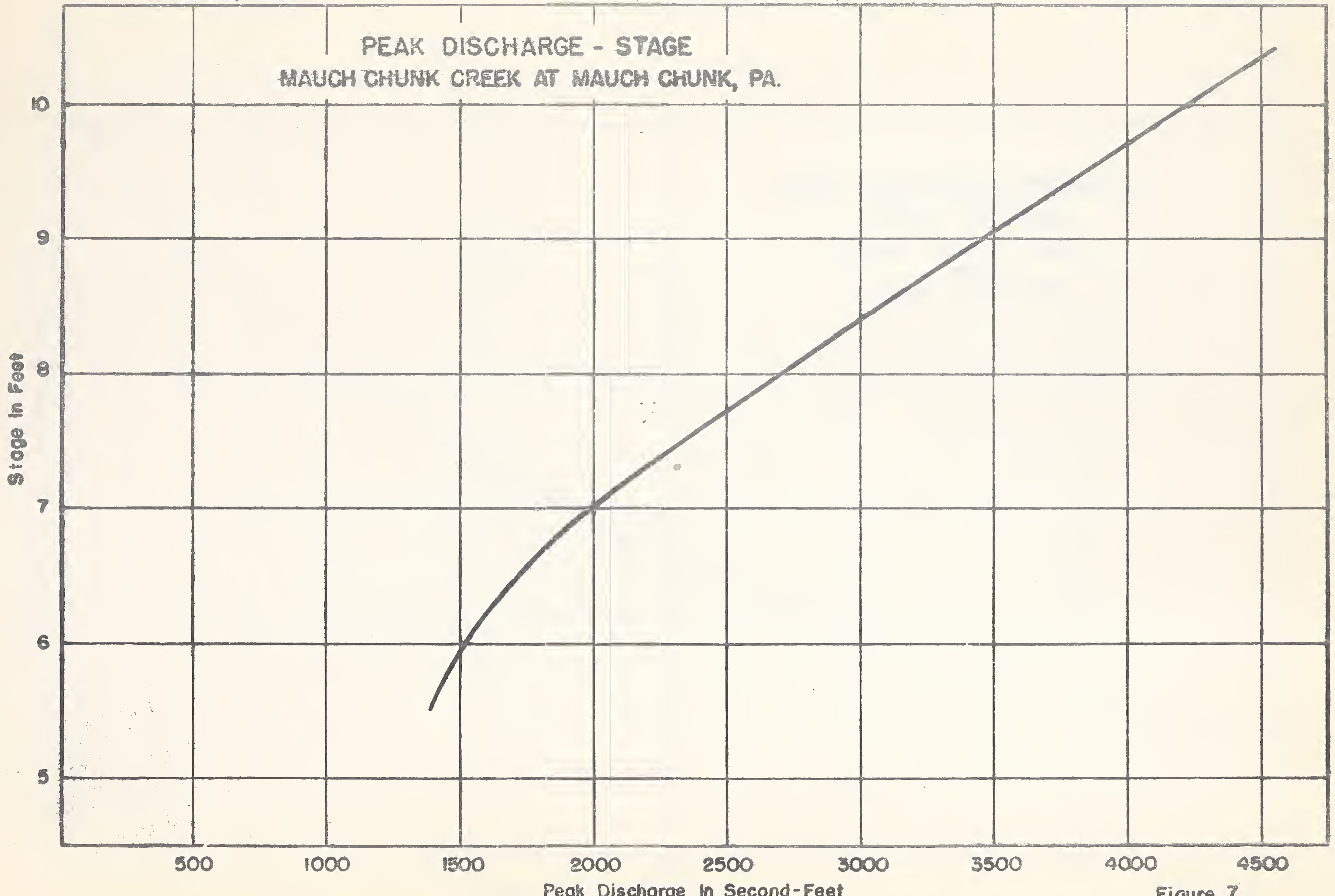

Figure 7

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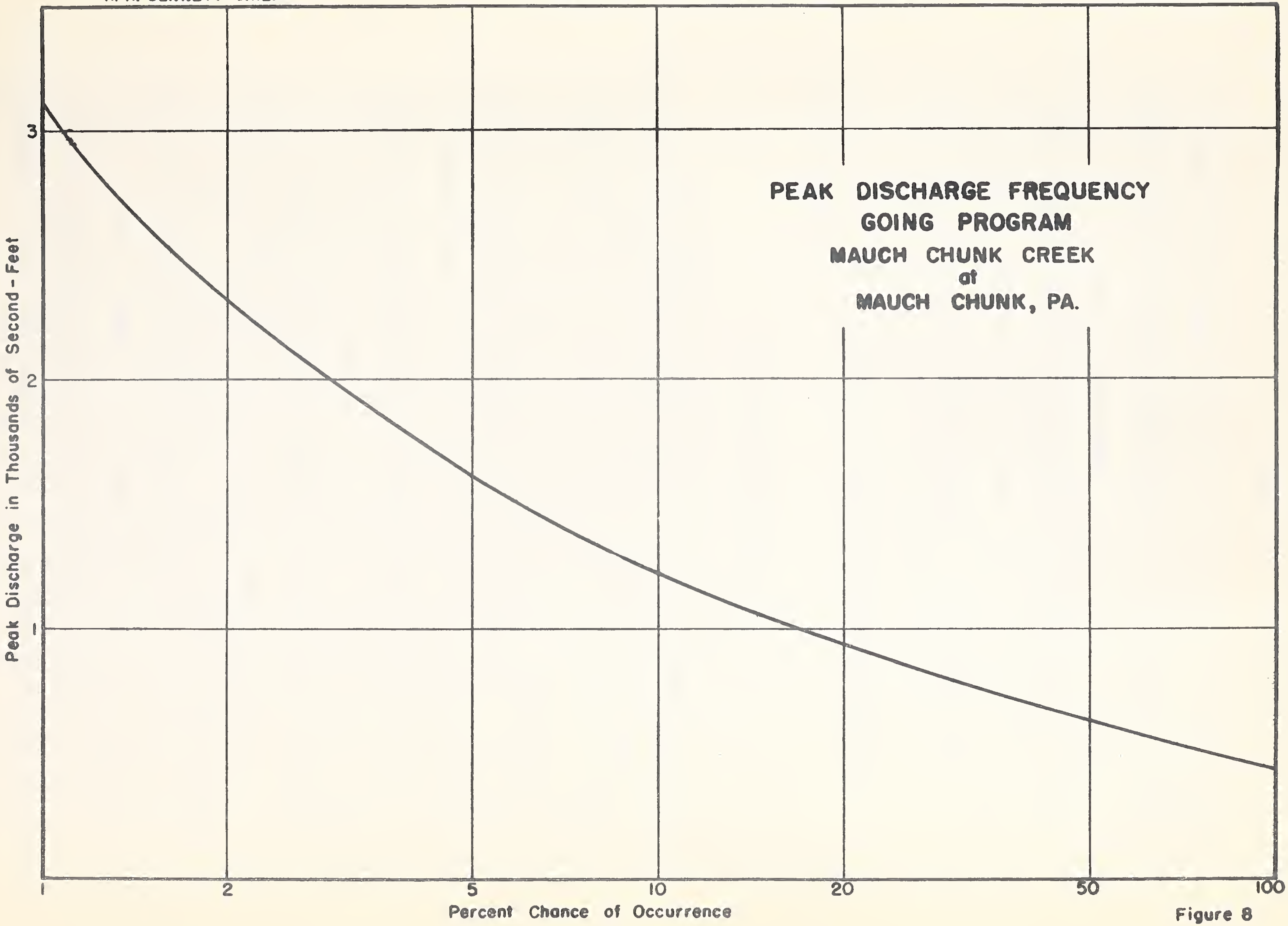


Figure 8

determined by the method illustrated in Appendix IV. The average annual damage, as computed from figure 5, is based on all floods whose percent chance of occurrence is less than 100. However, in the computation, it is assumed that the damage does not exceed that shown for the one percent flood. Table 3 shows the average annual damages by various subwatersheds. In computing these values cognizance was taken of the influence of authorized programs and current activities of federal and state agencies on flood control.

Flood Damage Appraisal

Flood damages are commonly classified as direct and indirect. By direct damage is meant the physical destruction and loss resulting from direct contact with flood water while indirect damage includes all other losses associated with floods. The damages shown in this report include both direct and indirect. They were not separated due to the complexity of their distinction and the difficulty of property owners reporting damages in those terms. However, where it was necessary to appraise indirect damages, they were developed to include such costs as evacuation and reentering premises, erecting temporary shelters and flood fighting, and higher costs of business operation. Other indirect losses included were the value of lost use of property during the period of restoration, and loss of labor to the extent that it was not accounted for by emergency work, such as flood fighting, evacuating goods, cleaning up, etc. Those damages such as losses in the volume of

trade through the reduced flow of goods from the flood area to the channels of trade and industry and through the decreased incomes of the owners of flood plain property were not evaluated. No monetary value was assigned to intangible losses, such as loss of life, illness, inconvenience, and disruption in social activities. Intangible damages were very large during and immediately following major floods, such as those in 1947, 1945, and 1942.

Table 3. Average Annual Flood Damage in the Delaware River Watershed (1949 Prices)

Tributaries	Average Annual Flood Damage
	(dollars)
West Branch Delaware	18,600
East Branch Delaware	17,300
McMichaels Creek	800
Cherry Creek	800
Pequest River	238,200
Bushkill Creek	35,300
Lehigh River	239,200
Lopatcong Creek	15,500
Tohickon Creek	700
Neshaminy Creek	2,300
Schuylkill River	216,800
Chester Creek	41,800
Brandywine Creek	21,200 1/
Red Clay Creek	8,100
White Clay Creek	1,100
Coastal Plain Tributaries	54,900
Miscellaneous Upland Tributaries 2/	148,700
Miscellaneous Piedmont Tributaries 2/	591,400
TOTAL AVERAGE ANNUAL DAMAGE	1,652,700

1/ The 1942 and 1927 floods caused large amounts of damages to one of the large industrial plants in the watershed. In computing average annual damage, these losses were not used because, at the time, sufficient information was not available to determine whether such losses would reoccur from similar flood discharges.

2/ These damages were developed by studies of sample tributaries.

In appraising damages by flood stage, in many instances experienced flood damages were enumerated and used as the basis of appraisal. In those cases where a property was destroyed and not replaced, the damage was considered non-recurring and was, therefore, not used. In the case of a highway bridge destroyed and replaced by a structure capable of withstanding higher flood flows, the damage was considered non-recurring and modified downward to reflect the damage if the flood flow were to reoccur.

The amount of damage to growing crops varies with the season of inundation. Growing crop damages were, therefore, computed by months to reflect these variations and averaged in accordance with the probable seasonal occurrence of flood flows. The amount of damage to various crops by depth of inundation during different stages of growth was estimated from data collected from farmers who had experienced recent crop damage. Approximately 47,400 acres of crops and 66,200 acres of pasture in the watershed are affected directly by inundation.

Sediment Damages

In the headwater areas of the Upland section, materials such as gravel, boulders, vegetation, and other debris moved by swift flowing streams, during times of high discharge, are dropped on flood plains and in channels where the velocity slackens. The gravel bars in channels often divert the flow of streams against banks or over the bank where damage is done to crops, pasture, roads, and other properties. Losses caused by this aggradation were included with flood damages.

In many low gradient streams sedimentation is partially responsible for frequent flooding. Because of frequent flooding the bottomland is used less intensively than its capability would otherwise permit. Where the recommended program makes possible more intensive use of this land, the benefit is included as "land enhancement".

Other types of damages resulting from sedimentation are as follows:

1. Increased dredging costs of navigable streams and harbors.
2. Increased maintenance costs of highways.
3. Loss in reservoir storage capacities.
4. Increased water treatment costs.
5. Loss in fish and wildlife values.

Dredging Costs - From studies of the sediment dredged from the Delaware River and Philadelphia Harbor it is difficult to determine what proportion of the material is the result of land erosion. Therefore, an approximation of the amount of eroded sediment reaching the tidal portion of the Delaware River was calculated from records of suspended sediment carried by tributary streams. The Brandywine Creek carries in suspension sediment equal to .15 acre-foot per square mile of its drainage area per year. The corresponding figure for Piedmont streams of less than 10 square miles of drainage area is computed as .35 acre-foot. Annual sediment production rates in the Upland section are estimated at .15 acre-foot per square mile in drainage areas up to 10 square miles and at

.11 acre-foot in drainage areas larger than 10 square miles.

An estimated 2,300,000 cubic yards (1,425 acre-feet) of material eroded from land surfaces, and exclusive of coal mine and industrial solids, are carried in suspension by the main and tributary streams annually. At least half of this material is deposited in the channel of the Delaware or adjacent to dock installations where dredging is necessary. A cubic yard of the material, as it comes from the land, weighs about 2,000 pounds; a cubic yard of sediment, as dredged, contains about 800 pounds of solids, the balance being water. The 1,150,000 cubic yards which settle out annually are equal to 2,875,000 cubic yards as the material is dredged $\left(\text{ratio of } \frac{2,000}{800}\right)$. At 26 cents per cubic yard an annual dredging cost of $747,500 is calculated as due to sedimentation from land erosion.

Increased Maintenance Cost of Highways - Increased costs of highway maintenance, due to sedimentation, were determined by conferring with state, county, and municipal highway engineers and officials. State and county highway officials were contacted in each county having an appreciable area in the watershed. Road supervisors of at least three representative townships or towns in each county were also visited. Based on cost records and opinions of these officials, the annual maintenance cost of highways in the watershed, due to sedimentation, is estimated at $135,000.

Loss in Reservoir Storage Capacity - A study was made of losses of reservoir storage capacities due to sedimentation. All

reservoirs of known storage capacity and watershed drainage area were considered in this study. In the final analysis the reservoirs with storage capacities between 30 and 150 acre-feet per square mile of drainage area were included. Reservoirs with storage capacities of less than 30 acre-feet per square mile of drainage area become filled with sediment from stream bedload. On the other hand, the annual loss of storage capacity in those reservoirs whose initial storage is above 150 acre-feet per square mile of drainage area is usually so low as to be economically unimportant. Annual sediment production rates used in determining the loss of reservoir storage were the same as those used in computing sedimentation in the portion of the river which is dredged.

Twenty-five reservoirs in Pennsylvania, 14 in New Jersey, and 2 in New York are within the group having 30 to 150 acre-feet capacity per square mile of drainage area. For these 41 reservoirs studied, totaling 27,562 acre-feet of storage, the annual rate of storage loss is 64 acre-feet, or less than .24 percent of the total. Due to the relatively low rate of loss no monetary damage was assigned.

Water Treatment Costs - The cost of removing sediment from surface water supplies for domestic consumption is related to the turbidity of the water. Turbidities of 100 or more parts per million were considered as being due largely to surface erosion, and hence would be affected by the recommended program. Studies were made of the records of several municipal water companies to determine the additional costs of water treatment when the turbidity is greater

than 100 parts per million. Based on the cost of alum required, the additional costs are approximately $15,600 annually for the watershed.

Losses in Fish and Wildlife - The harmful effect of sediment on fish and wildlife has not been evaluated in monetary terms. The problem of evaluation is complicated and difficult in part because the pollution of waters is also caused by industrial and coal mining wastes. The benefits derived from reducing pollution and sedimentation caused by land erosion are in part dependent upon the reduction of pollution by other sources. No value was placed on the damage to shellfish caused by sedimentation. The Shellfish Commissions in the States of Delaware and New Jersey indicated that reports of sediment damage to oysters have been very infrequent.

Erosion Damage

Based on studies of the Soil Conservation Service, the average annual rate of top soil loss from all cropland is .05, .11, and .05 surface inches respectively in the Upland, Piedmont, and Coastal Plain sections. From studies of the same source it was estimated that for each inch of the soil eroded crop yields would decrease five percent. Average yields, production and value of production for the area of cropland in the watershed that would be protected by the recommended program are shown in tables 18 and 19. As shown in these tables crop production was determined separately for lands recommended for retirement and for lands recommended for conversion practices. For each inch of top soil loss the annual value of crop

production would decrease approximately $735,000 in the Upland section; $1,624,500 in the Piedmont section, and $367,800 in the Coastal Plain section. Multiplying these values by the annual rates of soil loss in inches the annual cumulative loss would be $36,750, $178,700, $18,390, respectively in the three sections. It is reasonable to expect that these losses might continue for 50 years in the Upland and Coastal Plain sections and 25 years in the Piedmont section. At the end of these periods the top soil will have been reduced by approximately 2.5 inches and yields 12.5 percent. The present worth of the annual cumulative losses, using 4 percent interest, is $14,062,000 in the Upland, $30,687,000 in the Piedmont, and $7,037,000 in the Coastal Plain. For the total watershed the annual equivalent of the loss is $2,071,500.

Although the above computation of damage from erosion is based on the assumption of yield declines, the loss may occur through other or combination of other changes such as increased production costs in an effort to maintain yields, or lengthening crop rotations. The value of decreased production was accepted as a net loss, inasmuch as reductions in fertility mean little or no reduction in costs of raising the crop.1/ It was further assumed that damage from erosion would continue regardless of future improvements in seed, fertilizer, insecticides, etc. No erosion loss was calculated for pasture, since it is expected that going programs will have established , at the end of 20 years, most of the erosion control features of pasture land conservation practices.

1/ "One Method for Evaluating Effect of Measures to Prevent Erosion of Topsoil," by George H. Walter, "Agricultural Economics Research," April 1950, Bureau of Agricultural Economics.

Summary of Damages

A summary of all evaluated damages in the watershed is shown in table 4. In this summary an approximate division of the flood damages by type was made. About 56 percent of the damage occurred to industrial investments, 23 percent to agriculture, and the remaining 21 percent to highways and residential, commercial and other properties.

Table 4. Estimated Average Annual Monetary Damage
Delaware River Watershed
(1949 Prices)

Type of Damage	Average Annual Damage	
	(dollars)	
Damage Due to Inundation		
Highway	138,300	
Industrial	924,000	
Commercial	79,800	
Residential	99,200	
Agricultural	373,100	
Other	38,300	
Subtotal		1,652,700
Damage Due to Sediment		
Harbor and Channel Dredging	747,500	
Highway	135,000	
Water Treatment	15,600	
Subtotal		898,100
Damage Due to Erosion		2,071,500
TOTAL AVERAGE ANNUAL DAMAGE		4,622,300

III. PROGRAM

Needs of the Watershed

The basic need of the watershed is the establishment of an integrated runoff and waterflow retardation and erosion control program which includes (1) land treatment measures and practices and (2) structural measures primarily for flood control.

Improvement of vegetative cover through management, realignment of crop fields in contour strips, and establishment of water disposal systems which will protect the land from excess runoff are of primary importance to a flood control program. The component parts of the program must be fitted to land capabilities and needs, the economic and use patterns, the kind and locations of damages and nature of the problems involved.

There is an increasingly heavy demand on the watershed for domestic and industrial water supplies. New York City is permitted to divert 440 million gallons per day from the Delaware River. This amount is not enough to adequately supplement the limited supplies from other sources. Water supplies in the metropolitan area of northern New Jersey are rapidly becoming inadequate, and in some cases critically short. Greatly increased demands for water in the Philadelphia area and in such industrial centers at Bethlehem and Coatesville, Pennsylvania have caused full realization of problems immediately ahead. Pollution in the lower portion of the Delaware is often acute. All these conditions emphasize the need for careful conservation and utilization of surface waters which are possible only under a coordinated watershed program.

Determination of Needs

Land Treatment Measures and Practices

Openland - Areas of openland devoted to different uses were determined from the 1945 U. S. Agricultural Census. Information was collected by minor civil divisions, on acreages of total crop, pasture, other open farmland, and grazed woodland, in addition to the areas of specific crops. Figures for land use in minor civil divisions were combined to give areas by subwatersheds, counties, states and physical sections of the watershed. Numbers of livestock, especially beef and dairy cattle, were determined from the census as a guide in calculating the acreage of pasture required.

Twenty-one soil conservation districts are wholly or partly within the Delaware River Watershed. Conservation plans have been prepared for more than 4,000 farms in these districts. Only 1/8 % sample Twenty farm plans from each county in a soil conservation district were selected as samples from which to determine the openland needs of the watershed. These sample farms were selected to adequately represent range of topography, soil, type of agriculture, and size of farm.

Basic information on land use changes and conservation needs was secured from 360 farms. Expansion of this information to the acreages of similar land and land use in each section of the watershed was made on an areal basis. Some slight adjustments to local conditions were made in accordance with recommendations of technicians familiar with the conditions and problems.

Woodland - The extent and intensity of needed measures were determined from a woodland inventory of the watershed 1/ 2/. This inventory was made by analyzing aerial photographs, with field checks to substantiate the photographic analysis. It revealed present conditions and indicated the steps necessary to remedy them. Local, state, and federal agencies contributed information and advice on the development of the watershed needs. These data were supplemented by a field survey of sample watersheds representative of the three physical sections in the watershed.

Additional Measures

The needs of the watershed relative to such flood control measures as retarding structures, channel improvement, and diking were determined by several methods.

For small tributaries, up to approximately 20 square miles in size, studies were made of the samples used for damage appraisal. By the use of damage information for each tributary, tabulated by frequency of occurrence and the discharge-frequency curves applicable to the area, flood control measures were planned to reduce concentrated damage within the tributary. The benefit and cost of each measure were determined. The amounts of these measures that showed benefits in excess of costs were then projected to the areas represented by the samples to serve the needs of the watershed.

To determine the needs for channel improvement, water retarding structures and diking on the larger tributaries, a detailed study

1/ Inventory of forest conditions currently being carried out by the Northeastern Forest Experiment Station as a part of a National Forest Survey.

2/ Appraisal of forest statistics for the Middle Atlantic Region revised November 1945 by the Northeastern Forest Experiment Station.

was made of each high damage reach. Costs and benefits of individual measures were determined and only those measures which showed benefits in excess of costs were included in the needs.

Table 5 lists the estimated total land treatment measures needed in the Delaware Watershed.

Table 5. Total Watershed Needs
Delaware River Watershed

Practice	Unit	Quantity
I. Land Treatment Measures and Practices		
Contour Strip Cropping	Acre	1,329,400
Cover Cropping	Acre	1,104,700
Diversions and Terraces	Mile	4,760
Outlets and Waterways	Acre	9,380
Establishing Perennial Hay	Acre	347,750
Pasture Management	Acre	941,400
Pasture Improvement	Acre	807,000
Contour Furrowing	Acre	147,100
Streambank Erosion Control	Mile	277
Erosion Control Structures	No.	15,800
Woodland Management	Acre	3,976,600 1/
Tree and Shrub Planting	Acre	300,100
Land Acquisition	Acre	167,600
II. Additional Measures		
Stream Channel Improvement	Mile	423
Water Retarding Structures	No.	133
Diking	Mile	17

1/ Includes 276,000 acres of non-commercial woodland on which the only corrective measure needed is stabilization of roads and trails.

Land use adjustments for the watershed were determined according to the needs and capabilities of the land. In making these determinations consideration was given to the use of associated measures, such as contour strip cropping and diversions. These adjustments will provide substantial reductions in flood and sediment damage.

The land use changes needed involve, principally, reductions in acreages of clean tilled and grain crops, poor pastures, grazed woods and idle land, and increases in acreages of hay, good pasture and good woodland. Actual changes in acreages of each land use, while dependent on capabilities, will also be influenced by such factors as location on the farm, field arrangement, stoniness and drainage condition of soil.

Table 6 shows total needed land use adjustments.

Activities Related to Flood Control

General Statement

Several programs being carried on currently by various federal and state agencies relate to flood control. Work in the Department of Agriculture related to flood control is carried on primarily by four agencies--Production and Marketing Administration, Forest Service, Extension Service, and Soil Conservation Service.

The Production and Marketing Administration makes payments as conservation aids to individual farm owners for the application of several types of measures and practices in every county in the watershed. The most common of these practices are the improvements of hay and pasture lands through lime and fertilizer applications. Payments are also made for such measures as establishment of hay and pasture, construction of diversions and terraces, strip cropping, maintaining grassed waterways, the use of cover crops or mulching, tree planting, protection from grazing, and for timber stand improvement.

Table 6. Needed Land Use Adjustments
Delaware River Watershed

Use of Land	Present	Future	Net Adjustments	
	(acres)	(acres)	(acres)	(percent)
Clean Tilled Crops	667,600	595,400	- 72,200	- 10.8
Grain Crops	493,300	421,600	- 71,700	- 14.5
Hay Crops	747,900	909,100	+ 161,200	+ 21.6
All Cropland	1,908,800	1,926,100	+ 17,300	+ 0.9
Good Pasture	344,000	938,900	+ 594,900	+ 172.9
Poor Pasture	506,800	151,500	- 355,300	- 70.1
All Pastureland	850,800	1,090,400	+ 239,600	+ 28.2
Miscellaneous Openland	1,278,600	521,100	- 757,500	- 59.2
Grazed Woodland	178,000	21,000	- 157,000	- 88.2
Ungrazed Woodland	3,498,500	3,955,600	+ 457,100	+ 13.1
Wildlife	-	200,500	+ 200,500	-
Impervious, Roads, Urban, Streams	454,900	454,900	-	-
TOTAL	8,169,600	8,169,600	-	-

The Forest Service, as provided for under the Clarke-McNary and Norris-Doxey laws, cooperates with states in fire protection, reforestation, and establishing sound forestry practices. Satisfactory progress has been made in fire protection. The average annual burn has been reduced until it is not serious from a watershed protection standpoint.

The Extension Service is cooperating with the State Extension Services which, through their county agricultural agents and extension specialists, are currently conducting an educational program in the counties of the watershed aimed at increasing the application of many of these measures and practices.

The Soil Conservation Service is furnishing technical services to soil conservation districts for the planning and installation of soil and water conservation practices and measures.

The recommended measures for the Delaware River Watershed include the intensification, acceleration and adaptation of these activities.

Through these existing authorities the Department of Agriculture is now expending $947,400 annually in the Delaware River Watershed to carry out these activities.

Flood control reservoirs are proposed by the Department of the Army, Corps of Engineers for construction on the Lehigh and Lackawaxen Rivers. Local improvement works are also proposed for Allentown and Bethlehem, Pennsylvania.

The Corps of Engineers has completed local flood protective works on the Rancocas Creek at Mount Holly, New Jersey. An existing

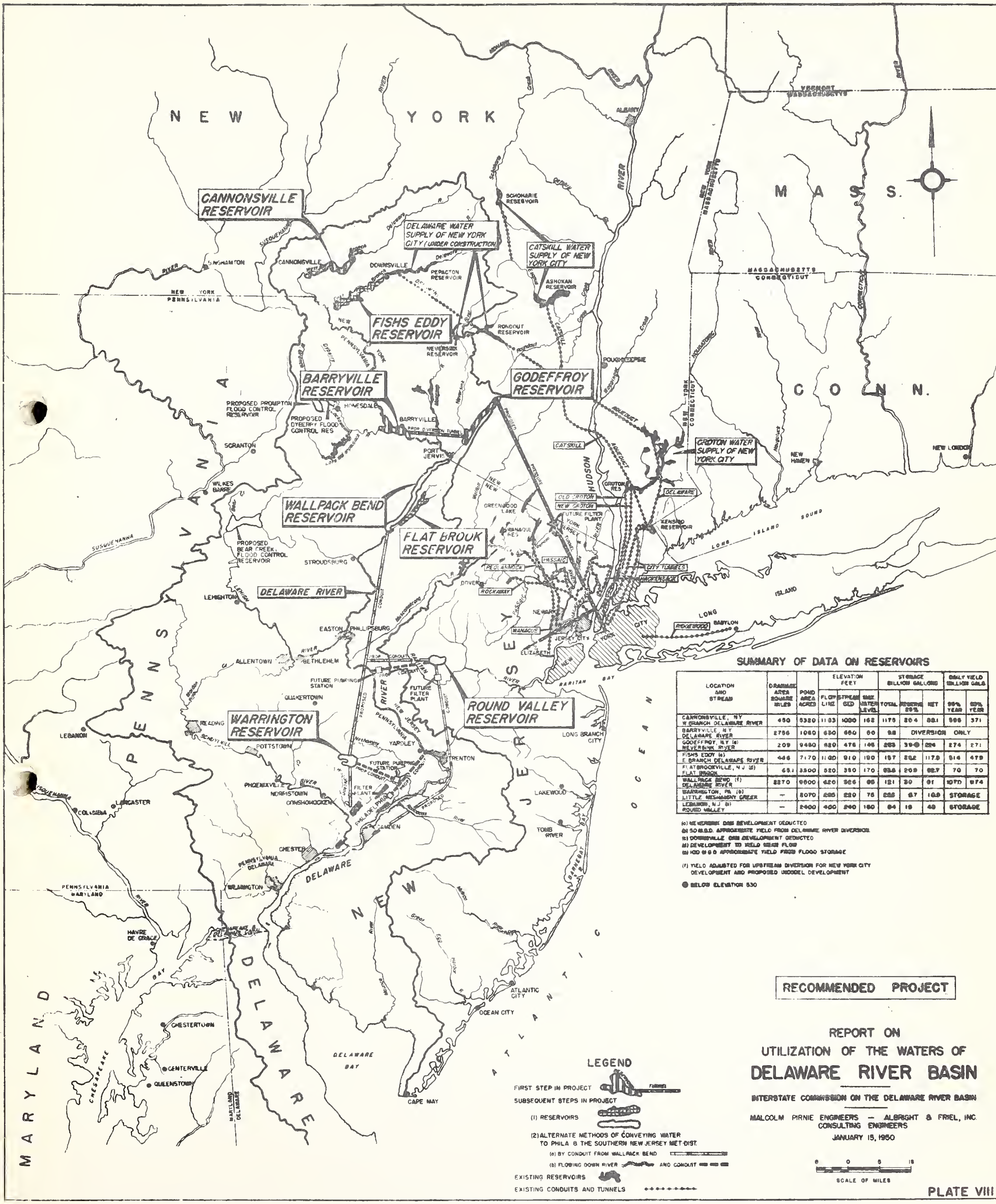
project authorizes the Corps of Engineers to dredge the Schuylkill River channel between Norristown and Philadelphia, Pennsylvania.

The state and other local agencies administer certain lands in public ownership. In general, these are being managed in accordance with the aims and objectives of the recommended flood control program.

The Commonwealth of Pennsylvania is carrying out the remainder of the improvement work on the Schuylkill River, the principal objective being to keep coal wastes from mining operations out of the river, and the elimination of the culm already in the channel by dredging and by the use of desilting basins. Important benefits to be expected from this project are reduction in flood damage and greatly reduced sedimentation in the lower Schuylkill and the Delaware River below Philadelphia.

Soil conservation districts organized under state laws, are operating in 29 of the 43 counties wholly or partly within the watershed. These districts have developed a program of soil and water conservation and proper land use on farm lands.

The Interstate Commission on the Delaware River Basin, created by joint action of the States of Delaware, Pennsylvania, New Jersey, and New York, and popularly known as Incodel, is making a survey of the water resources of the watershed, which will result in recommendations for the development and conservation of these resources. A preliminary report on this survey has been made public which tentatively recommended the program as shown on the following map.



SUMMARY OF DATA ON RESERVOIRS

LOCATION AND STREAM	DRAINAGE AREA SQUARE MILES	POND AREA ACRES	ELEVATION FEET: FLOW LINE	ELEVATION FEET: STREAM BED	ELEVATION FEET: MAX. WATER LEVEL	STORAGE BILLION GALLONS: TOTAL	STORAGE BILLION GALLONS: RESERVE 20%	STORAGE BILLION GALLONS: NET	DAILY YIELD MILLION GALS: 95% YEAR	DAILY YIELD MILLION GALS: 99% YEAR
CANNONSVILLE, NY W BRANCH DELAWARE RIVER	450	5320	1183	1020	162	1175	204	83.1	396	371
BARRYVILLE, NY DELAWARE RIVER	2756	1060	630	564	60	9.8	DIVERSION ONLY			
GODEFFROY, NY (a) NEVERSINK RIVER	209	9480	620	476	146	283	39●	224	274	271
FISHS EDDY (c) E BRANCH DELAWARE RIVER	446	7170	1100	910	190	157	282	117.8	514	479
FLATBROOKVILLE, NJ (d) FLAT BROOK	68.1	3500	520	350	170	83.6	209	62.7	70	70
WALLPACK BEND (f) DELAWARE RIVER	3270	9600	420	326	95	121	30	91	1070	874
WARRINGTON, PA (b) LITTLE NESHAMINY CREEK	—	5070	295	220	75	226	57	169	STORAGE	
LEBANON, NJ (e) ROUND VALLEY	—	2400	400	240	160	64	16	48	STORAGE	

(a) NEVERSINK DAM DEVELOPMENT DEDUCTED
(b) 50 M.G.D. APPROXIMATE YIELD FROM DELAWARE RIVER DIVERSION
(c) DOWNSVILLE DAM DEVELOPMENT DEDUCTED
(d) DEVELOPMENT TO YIELD MEAN FLOW
(e) 100 M.G.D. APPROXIMATE YIELD FROM FLOOD STORAGE

(f) YIELD ADJUSTED FOR UPSTREAM DIVERSION FOR NEW YORK CITY DEVELOPMENT AND PROPOSED [illegible] DEVELOPMENT

● BELOW ELEVATION 530

LEGEND

FIRST STEP IN PROJECT
SUBSEQUENT STEPS IN PROJECT
(1) RESERVOIRS
(2) ALTERNATE METHODS OF CONVEYING WATER TO PHILA & THE SOUTHERN NEW JERSEY MET. DIST.
(a) BY CONDUIT FROM WALLPACK BEND
(b) FLOWING DOWN RIVER AND CONDUIT
EXISTING RESERVOIRS
EXISTING CONDUITS AND TUNNELS

RECOMMENDED PROJECT

REPORT ON
UTILIZATION OF THE WATERS OF
DELAWARE RIVER BASIN

INTERSTATE COMMISSION ON THE DELAWARE RIVER BASIN

MALCOLM PIRNIE ENGINEERS — ALBRIGHT & FRIEL, INC.
CONSULTING ENGINEERS
JANUARY 15, 1950

5 0 5 15
SCALE OF MILES

PLATE VIII

If and when these recommendations are put into effect the program herein recommended will be adjusted to furnish optimum watershed protection for the structures.

Within the watershed are numerous private associations and groups such as the Lehigh Valley Flood Control Council and the Brandywine Valley Association which are directly or indirectly concerned with flood control.

The Brandywine Valley Association is taking the lead in Brandywine Creek Watershed in an educational program which covers all phases of watershed improvement and the reduction of stream pollution. They are very actively supporting all phases of a conservation program and are making the public aware of the existing problems, and the benefits to be expected from a solution of the problems.

The Lehigh Valley Flood Control Council is active in developing a flood protective program for the Lehigh River Watershed. This council was organized following the flood of 1942 and has rendered valuable assistance in making flood damage surveys and in securing federal and other assistance for developing the details of the needed protection programs. Reference has been made to the Lehigh River under activities of the Corps of Engineers.

Local improvements along Frankford Creek, a tributary entering Delaware River within the city limits of Philadelphia, are being constructed by the city. The work consists largely of channel improvements along 4 miles of stream where flood runoff damages have been excessive.

Protective works, principally earth diking, along the Delaware River at Morrisville, Pennsylvania, were constructed as a W.P.A. project. Overbank flooding at Morrisville has been largely eliminated.

Recommended Program

The following recommended program includes the intensification, acceleration, and adaptation of certain activities under current programs of the Department of Agriculture as described under "Activities Related to Flood Control". The recommended program, including land use adjustments, is deemed of primary importance to the objective of the flood control act and does not include measures or practices for the primary purpose of increasing production. For example, items such as: the application of fertilizer after the installation or establishment of a measure has been completed; farm water supply and distribution systems exclusively for the purpose of livestock and domestic use; drainage and irrigation for increased production; tree planting or timber stand improvement for timber production only; and the installation of recreational facilities are not included as part of the recommended program. Included in the recommendation are additional measures not now regularly installed but considered necessary to complete a balanced program for runoff and waterflow retardation and soil erosion prevention. These measures are shown in tables 7 and 8, and are referred to throughout the report and appendixes as the recommended program. The individual measures and practices are described on the following pages.

Table 7. Recommended Program Measures
Delaware River Watershed

Practice	Unit	Quantity
I. Land Treatment Measures and Practices		
Contour Strip Cropping	Acre	870,500
Cover Cropping	Acre	118,400
Diversions and Terraces	Mile	3,040
Outlets and Waterways	Acre	6,480
Establishing Perennial Hay	Acre	281,400
Pasture Management	Acre	685,900
Contour Furrowing	Acre	147,100
Streambank Erosion Control	Mile	275
Erosion Control Structures	No.	9,800
Woodland Management	Acre	3,976,600 1/ 257,840
Tree and Shrub Planting	Acre	256,600
Land Acquisition	Acre	167,600
II. Additional Measures		
Stream Channel Improvement	Mile	423
Water Retarding Structures	No.	133
Diking	Mile	17

1/ Includes 276,000 acres of non-commercial woodland on which the only corrective measures recommended is stabilization of roads and trails.

Table 8. Recommended Land Use Adjustments
Delaware River Watershed

Land Use	After 20-Years Going Programs	Recommended Program	Net Adjustments	
	(acres)	(acres)	(acres)	(percent)
Clean Tilled Crops	654,600	595,400	- 59,200	- 9.0
Grain Crops	480,400	421,600	- 58,800	- 12.2
Hay Crops	776,900	909,100	+ 132,200	+ 17.0
All Cropland	1,911,900	1,926,100	+ 14,200	+ 0.7
Good Pasture	451,100	938,900	+ 487,800	+ 108.1
Poor Pasture	442,800	151,500	- 291,300	- 65.8
All Pastureland	893,900	1,090,400	+ 196,500	+ 22.0
Miscellaneous Openland	1,154,000	521,100	- 632,900	- 54.8
Grazed Woodland	149,700	21,000	- 128,700	- 86.0
Ungrazed Woodland	3,569,100	3,955,600	+ 386,500	+ 10.8
Wildlife	36,100	200,500	+ 164,400	+ 455.4
Impervious, Roads, Urban, Streams	454,900	454,900	-	-
TOTAL	8,169,600	8,169,600		

Openland

The openland measures will reduce erosion and runoff through changes in land use and the adoption of improved cultural and management practices,

Contour Strip Cropping - This measure is the growing of hay or other close growing, soil conserving crops in alternate contour strips with clean tilled or soil depleting crops. Such a measure maintains at least half of sloping fields in hay or close growing crops which will filter out any eroded soil from a clean tilled crop above and thus keep the soil on the field. Contour cultivation, which is included with contour strip cropping in this report, is used to protect gently sloping land or small fields where strip cropping is not feasible. Contour cultivation and contour strip cropping reduce the rate and amount of runoff by increasing infiltration rates and by providing temporary surface storage. The removal of hedgerows or other obstructions is necessary on many farms for proper installation of contour strip cropping.

Cover Cropping - This practice refers to the growing of temporary crops for the purpose of soil protection during off seasons for regular crops or during periods when the land would be idle or fallow. Cover cropping protects the soil from erosion by reducing the impact of rainfall, and reduces runoff through better infiltration conditions. This measure includes application of mulches, which are normally organic matter grown elsewhere and applied to critical areas. The organic matter added by cover cropping and mulching increases the water holding capacity of the soil.

Diversions and Terraces - Diversions and terraces are grouped as one measure since they have the same general function; intercepting surface runoff and carrying it across slopes in designed channels. Diversions are normally kept in perennial hay, while terraces are used for the same crop as the contiguous land. Both diversions and terraces are used in connection with strip cropping and contour cultivation, and by removing excess surface water, facilitate the control of erosion by vegetative means. The removal of hedgerows and other obstructions is often necessary for the installation of this measure.

Outlets and Waterways - Natural drainage ways are used wherever possible for disposing of water from diversions and terraces. They are usually stabilized and protected by permanent grass cover. Where grass will not provide a safe cover, additional protective measures, such as drop structures, chutes, or flumes will be used. These mechanical measures are included under another heading. Properly constructed and protected outlets and waterways will appreciably reduce gully erosion and sedimentation damage.

Establishing Perennial Hay - Vegetative cover consisting of long-lived legumes and grasses suitable for hay is recommended for those areas where clean tilled crops cannot be safely grown in rotation. Reseeding of the hay mixture will be done at infrequent intervals with as little cultivation of the land as possible. Perennial hay is also recommended for use in protecting diversions. Runoff and erosion from critical areas will be greatly reduced by adequate hay cover.

Pasture Management - The objective of pasture management is the maintenance of adequate vegetative cover on land used for permanent pasture to reduce erosion and runoff. Mowing to control weeds and remove mature grasses, scattering of droppings, regulating the intensity of grazing are essential to good pasture management. Additional fencing is usually required for adequate control of grazing. Certain areas of pasture land are rough or are partially covered by trees or brush. Where necessary these obstructions will be removed.

Contour Furrowing - Level furrows or small level terraces with no outlet will be constructed for the storage of water on pastured slopes where vegetative cover is inadequate. Temporary storage, equivalent to one-half inch of runoff for the area treated, will be available in the furrows.

Streambank Erosion Control - Eroding streambanks on small tributary streams cause sedimentation damage downstream and loss of flood plain land adjacent to the streams. Erosion control for such banks involves sloping the banks and protecting them by mechanical means such as riprap or by suitable vegetation.

Erosion Control Structures - These include such measures as small check dams, gully structures, and culverts where they are a necessary part of the water disposal system or are required for gully stabilization. The concentration of runoff water by a water disposal system makes it necessary that special erosion control structures be used to protect the channels or natural drainageways from gullying and to furnish protection to railroad and highway ditches. New and larger culverts will be necessary to safely pass

runoff water under railroad and highway fills. The establishment of these measures will reduce the rate of gully erosion in existing drainageways and permit the installation of adequate water disposal systems which will materially reduce sheet and gully erosion on the fields protected.

Woodland

The purpose of the recommended program is to build up and maintain cover and soil conditions that (provide and grow maintain) optimum watershed relations. Installation of the program measures is expected to increase the infiltration rate and the water holding capacity of the soil. This will result in a decrease in rapid ~~surface~~ runoff of water and in soil ~~deterioration and~~ erosion.

Four general measures are proposed for woodland areas, to meet the above objectives: improved forest management practices; increased forest acreage by converting certain crop, pasture, and idle lands to woodland in accordance with the needs and capabilities of the land; protection from grazing; and public acquisition of critical areas to insure adequate management.

On certain types of public lands some standards and practices are not in line with the objectives of this program. Where reorientation of objectives and improvement of practices on these lands are limited by finances, the necessary measures and funds are included in the recommended program. ?

Woodland Management - Forests affect watershed values largely through their influence on the forest floor and the soil beneath down to the rooting depth. Studies have shown that stand density and age directly influence humus and soil conditions.

Analyses of the sample tributaries indicate that the present woodland hydrologic conditions can greatly be improved by building up and maintaining the forest cover and by careful cutting and logging practices. To attain these objectives, woodland management will be improved and placed on a sound technical basis by application of the following measures and practices:

Management plans will be prepared for each property. This plan will integrate the dual objectives of watershed protection and timber production and will outline the important activities--such as planting, cultural operations, and harvest cuttings--to be carried out in order to maintain the woodland in the best possible condition for flood and sediment control and water conservation. Plans will be prepared for about 3,372,000 acres in private ownership and for 168,000 acres in public ownership.

Technical service on timber marking will be provided to woodland owners and operators at public expense. Clear cutting over extensive areas will be eliminated as a harvesting method by substituting selective cutting wherever applicable or by supplementing with shelterwood, patch, group, or strip cutting where silviculturally necessary. It is estimated that approximately 1,419,000 acres will be marked for harvest cuts during the installation period and 1,064,000 acres for cultural operations. In the main, cultural operations

will be confined to areas of shallow soil where it is necessary to build up soil moisture storage capacities by increasing the depth of humus and the amount of organic material in the soil profile. These objectives will be realized by the development of thrifty, mixed stands of those species which produce maximum amounts of leaves and litter for conversion into organic matter in the soil profile.

Corrective measures are recommended for areas which have been damaged by existing logging and skid road systems to correct the unstable conditions responsible for accelerated runoff and excessive sediment movement. Such roads are usually poorly located, have inadequate drainage facilities, and contribute excessively to flood runoff. Technical services will provide for the proper planning and locating of future road systems and outline the steps necessary to correct unsatisfactory conditions on existing logging roads. These include the installation of water bars, ditches, culverts, and other minor structures to spread water, and the regevetation of roadways after use.

Cultural operations are provided on 1,064,000 acres of shallow soils to rapidly build up thrifty, well stocked stands which will create optimum woodland hydrologic conditions in the shortest possible time.

Landowners are expected to carry out the needed operations once technicians have outlined the work to be done.

Guidance on improved utilization and marketing of forest products is necessary to make the recommended management system acceptable to the owners and to obtain their effective cooperation in the program. Technical service and information in this field will be made available to landowners, logging operators, and processors.

Livestock grazing will be eliminated on all but 21,000 acres of grazed woodland. It will also be eliminated on the presently grazed openland which is scheduled for conversion to woodland. This will require exclusion of livestock from 128,700 acres of grazed woodland and on 144,500 acres of openland scheduled for conversion to forest.

Tree and Shrub Planting - Land use adjustments in accordance with need and capability will require conversions of both openland and woodland. Approximately 300,100 acres of present openland will be converted to woodland by planting or allowed to revert naturally during the installation period. Of this total, about 292,100 acres will be involved in the recommended program. This area will be converted to woodland while 34,300 acres of woodland are converted to openland, principally for pasture, resulting in a net gain of 257,800 acres in woodland area. Surveys

show that at least 232,900 acres of the 292,100 acres to be converted to forest will have to be planted. The remaining 59,200 acres are favorably located with respect to seed sources and should restock naturally with desirable species.

Planting of shrubs is recommended on 23,700 acres. The planting of these shrubs in the edges between woodland and cultivated fields or pastures will provide good land cover in the partially shaded areas adjacent to woodland and aid in the reduction of surface runoff.

Land Acquisition - Acquisition of land by state and local governments is recommended only for land that is vital for watershed protection purposes. These areas are characteristically the ridge top and upper slope localities which, because of their location and past use, have poor woodland cover and contribute materially to flood problems. In general, these areas have suffered from repeated heavy cuttings and severe fires. Acquisition of these areas will, however, be undertaken only if it is clear that the present owners will not carry out the improvement measures necessary to restore the land to good watershed condition. It is expected that land will be purchased by state or local governments and maintained as a part of existing or new public forests and preserves.

Acquisition of private land is recommended only in the States of New York and Pennsylvania. The approximate areal extents and locations are as follows: New York - the areas to be considered consist of approximately 50,000 acres. Of this amount,

approximately 49,500 acres are woodland and 500 acres abandoned openland. The forest cover consists principally of young and inferior oak stands. Soil conditions are very unsatisfactory in these areas. The proposed acquisition areas fall within the water supply area of New York City. Pennsylvania - approximately 117,600 acres are recommended for purchase. Of this area, approximately 12,000 acres are abandoned farmland. In general, the area proposed for purchase in Pennsylvania is in the anthracite coal region.

In table 9 are shown the present and future areas of woodland, according to type of ownership.

Table 9. Ownership of Forest Land

Delaware River Watershed

	Present Area	Future Area with the Recommended Program 1/
	(acres)	(acres)
Privately Owned Woodland	3,240,000	3,272,500
Publicly Owned Woodland		
State and Local Governments	424,800	592,400
Federal Reservations	11,700	11,700
TOTAL	3,676,500	3,976,600

1/ Includes accomplishments of going program.

Additional Measures

Stream Channel Improvement - The objectives of this measure are to reduce the damages resulting from inundation of valuable bottomland, furnish flood protection for high-value improvements, such as farm buildings, and provide outlets for drainage works.

To accomplish these objectives the discharge capacity of stream channels will be increased by the removal of debris and sediment deposits, clearing and snagging, realignment, and bank sloping.

Water Retarding Structures - Upstream floodwater retarding structures will reduce inundation damage by providing temporary storage for flood runoff. These structures will be used primarily to protect urban areas where flood damages are high and other measures are impractical or inadequate. Drainage areas above the structures will average less than two square miles. The structures will be earth fill dams through which a small, low elevation outlet conduit, uncontrolled by gates or valves, will be constructed to draw down the temporary storage. A spillway adapted to site conditions and meeting required design criteria will be used to provide an outlet for flood flow in excess of the storage capacity which will be equivalent to approximately three inches of runoff from the watershed above the structure.

Diking - This measure provides protection from inundation of valuable bottomland and such improvements as highways and farm buildings where limitation of rights-of-ways and gradients prohibits the use of channel improvement. The dikes will be of earth fill construction with side slopes of $1\frac{1}{2}$:1, and generally will not exceed five feet in height. Floodways will be provided to safely carry flood discharges of design frequency.

IV. PHYSICAL EFFECT OF THE PROGRAM

Land Treatment Practices and Measures

Land cover conversions, woodland management, and certain of the openland measures recommended in the report, result in an increase in the rate and total amount of infiltration on the area affected. The resultant decrease in surface runoff reduces peak flow and damages due to inundation.

The physical condition of the forest floor, determines in the main, how the forested area affects flood runoff. A forest floor is made up of humus and litter. Studies of infiltration and soil moisture have shown that an increase in humus and litter depth and an improvement in humus condition (i.e. a change to a more porous type) are reflected in both a higher rate of water intake and a greater water storage capacity.

The effect of woodland measures on flood runoff was determined by comparing average forest floor conditions under all present stands with those conditions found under the better stands such as would prevail with the recommended program in effect.

On a field inventory of selected subwatersheds observations were made to determine the average condition and depth of the woodland humus by forest stand size and condition class, and past use or treatment including grazing, burning, logging, and whether or not the area had been cleared for agricultural purposes.

The field observations indicate that burning, grazing, and heavy cutting are detrimental to humus condition. Stands that have

experienced these conditions have a more compact and shallow humus. The better stocked, older stands showing no evidence of fire, grazing, or of clearing for agriculture, have deeper humus and litter.

The condition and depth of humus in well stocked, ungrazed, unburned stands of an older age class is taken as the condition to be expected with good woodland management. Those stands are by no means ideal; good forest management should result in appreciably better conditions.

Infiltration rates of forest soil profiles were correlated with forest flood conditions to permit a hydrologic evaluation of woodland areas. The forest area was grouped into three hydrologic evaluation classes based on forest floor conditions. The criteria for defining these classes (like those for the openland) apply to both present conditions and those with the program in effect. The hydrologic evaluation classes are as follows:

Class I (Woodland)

Deep humus of a highly absorptive type. Forest floor undisturbed and uniform.

Class II (Woodland)

Moderately deep humus of an absorptive type. Forest floor relatively undisturbed and uniform.

Class III (Woodland)

Shallow humus disturbed and patchy or deeper humus of a compact, less porous type.

Class IV (Openland)

Hydrologic conditions such as are found in good pasture. Highest openland infiltration. Includes good meadow or hayland.

Class V (Openland)

Infiltration and soil moisture transmission values of an intermediate openland condition. The hydrologic condition found with close growing crops such as small grains. Poor pasture and poor hayland were included in this class.

Class VI (Openland)

Poorest cropland hydrologic conditions. Runoff producing infiltration rates attributable to corn and other row crops.

Other Areas.

Includes road, urban and other areas of low permeability.

The areas of the several hydrologic evaluation classes under present conditions and with the recommended program in effect are given in table 10. In addition to the acreage, areas are expressed as percentages of the watershed and of the woodland or openland as applicable.

Table 10. Hydrologic Evaluation Class Area Relationships

Delaware River Watershed

Class	Present			With Recommended Program		
	Acres	% of Woodland	% of Total Area	Acres	% of Woodland	% of Total Area
I	1,066,200	29	13	2,704,100	68	34
II	1,691,200	46	21	1,153,200	29	14
III	919,100	25	11	119,300	3	1
		% of Openland			% of Openland	
IV	1,215,100	30	15	2,050,000	55	25
V	2,155,500	53	26	1,071,000	29	13
VI	667,600	17	8	616,500	16	7
Other	454,900		6	454,900		6
Total Woodland	3,676,500		45	3,976,600		49
Total Openland	4,038,200		49	3,738,100		45
Total Watershed	8,169,600			8,169,600		

The reasons that a portion (3 percent) of the wooded area will remain in Class III under management are: (1) a small area will be grazed; (2) a small area will be burned; (3) logging will destroy the humus on skid trails and log landings, and complete correction is not economically feasible; and (4) small areas of extremely steep topography and shallow, rocky soils will never build up an appreciable forest floor. The reasons for the future area remaining in evaluation Class II are largely natural ones. Because of unfavorable topographic and soil conditions the forest floor cannot be improved to the point where the area will fall in Class I. While forest management will improve these areas appreciably, natural factors prevent them from attaining the optimum condition.

The improvement in the forest floor resulting from increasing the area of well-stocked, well-managed forests, will decrease the amount of concrete soil freezing in winter. Studies throughout the Northeast have shown that hard freezing in woodlands is decreased by building up humus and litter depths. This reduction of impermeable frost will reduce surface runoff and increase soil moisture. By eliminating grazing and increasing stand stocking the problem of impermeable freezing as a factor influencing surface runoff in woodlands will be materially reduced.

Openland hydrologic evaluation classes follow closely the type of openland use to which each area is put. Most desirable use from a hydrologic standpoint is the raising of crops of perennials and of those annuals which need not be replanted each year.

Least desirable are the row crops which must be cultivated during the growing season. Intermediate between these are the close-growing crops such as the small grains. The program calls for changes in the areas devoted to the various openland uses as a measure toward an improved watershed hydrologic condition.

Changes in land use will result in the retirement of some openland to woodland, and the conversion within the openland to the classes having higher infiltration rates. Increased areas in evaluation Class IV will be derived almost entirely from areas now in Classes V and VI. The total net change will provide an improvement in hydrologic conditions as well as reduce soil erosion.

Reduction in Peak Discharge

The following procedures were used to determine: the infiltration rates of various evaluation classes; the amount of reduction in peak discharge caused by land use changes; the additional effect of woodland and openland measures; and the resulting total reduction in peak discharge.

Infiltration - Infiltration data, derived largely from infiltrometer studies, were used to establish infiltration rates for the major soil and cover types found in the watershed. Each of the many soil types was assigned to one of eight soil behavior groups according to its infiltration characteristics (table 11). Infiltration rates applicable to the six evaluation classes were assigned to each of the eight soil groups. An example for the Piedmont area is shown in table 12.

Table 11. Soil Groups by Physiographic Area for Hydrologic Evaluation

Delaware River Watershed

Physiographic Section	Soil Depth and Drainage	Soil Group	Representative Soil	Representative Soil Description	Other Soils
Upland	Deep, well drained	1	Lackawanna silt loam	Reddish silt loam friable at the surface, with large stone content and becoming compact with depth. Developed on red shales and sandstones on ridge positions with moderate slopes.	Walton, Bartown, and Tunkhannock
	Shallow, imperfectly and poorly drained	2	Culvers silt loam	Yellowish-red friable silt loam with compact dense subsoil	Canfield, Wurtsboro, and Braceville
Piedmont	Deep, well drained	3	Chester silt loam	Brown, friable, silt loam containing some gritty material, resting on a brownish-yellow gritty loam and grading into silty clay loam.	Glenelg and Neshaminy
	Shallow well drained	4	Manor stony loam	Yellowish-brown heavy loam resting on yellow clay loam. Both soil and subsoil contain from 30 to 60 percent of flat angular rock fragments.	Edgemont and Brandywine

Table 11, Soil Groups by Physiographic Area for Hydrologic Evaluation

Delaware River Watershed (continued)

Physiographic Section	Soil Depth and Drainage	Soil Group	Representative Soil	Representative Soil Description	Other Soils
Piedmont (continued)	Imperfectly drained	5	Glenville silt loam	Yellowish, friable silt loam mottled at moderate depth. Developed on schist and gneiss and occupying colluvial positions.	Readington, Lehigh and Strasburg
Coastal Plain	Coarse textured, deep, well drained	6	Sassafras sand	Dark gray loamy sand resting on orange-yellow sand, occupying rolling areas with moderate slopes.	Collington and Lakewood sands
	Medium textured, deep, well drained	7	Sassafras sandy loam	Light brown sandy loam over orange-yellow sandy loam resting on friable sandy clay.	Collington loam Sassafras gravelly loam and Sassafras loam
	Medium textured, imperfectly drained	8	Woodstown loam	Brown loam with pale yellow, friable, sandy clay, subsoil occupying flat or depressed areas.	Keyport sandy loam, Shrewsburg and Freneau

Table 12. Infiltration Rates
Values of f_c in inches per Hour at 600 Minutes

Chester Creek Watershed, Pennsylvania
Piedmont Area

Delaware River Watershed

Evaluation Class	Soil Group		
	3	4	5
Class I (Woodland)	1.68	1.05	0.42
Class II "	1.20	0.75	0.30
Class III "	1.08	0.67	0.27
Class IV (Openland)	1.20	0.75	0.30
Class V "	1.08	0.67	0.27
Class VI "	0.96	0.60	0.24

The changes in infiltration rate during a storm were found to be most satisfactorily accounted for by the use of a ϕ curve for each evaluation class (Fig. 9). A ϕ curve differs from a curve of infiltration rate in that any point on the ϕ curve represents an average value for the infiltration that has taken place in the elapsed time from the start of precipitation. These curves of necessity represent average conditions for the evaluation class but their use permits a satisfactory analysis of the runoff producing conditions of the watershed. The ϕ curves were used in the analysis of runoff from a series of storms developed for each area considered.

Land Use Changes - The procedure used in determining the amount of peak flow reduction to be expected from land use changes and other program measures follows a logical series of steps consisting of statistical and graphical analyses applied to the principal factors affecting flood damages. These steps are described below.

Sample tributaries for determining the hydrologic effect of the program were selected to represent the three physiographic sections of the watershed. Each section was represented by two samples. The samples are the watersheds above the gaging stations listed as follows:

Upland - West Branch of Delaware River at Delhi, New York.

- East Branch of Delaware River at Margaretville, New York.

Piedmont - Chester Creek near Chester, Pennsylvania.

- Brandywine Creek at Chadds Ford, Pennsylvania.

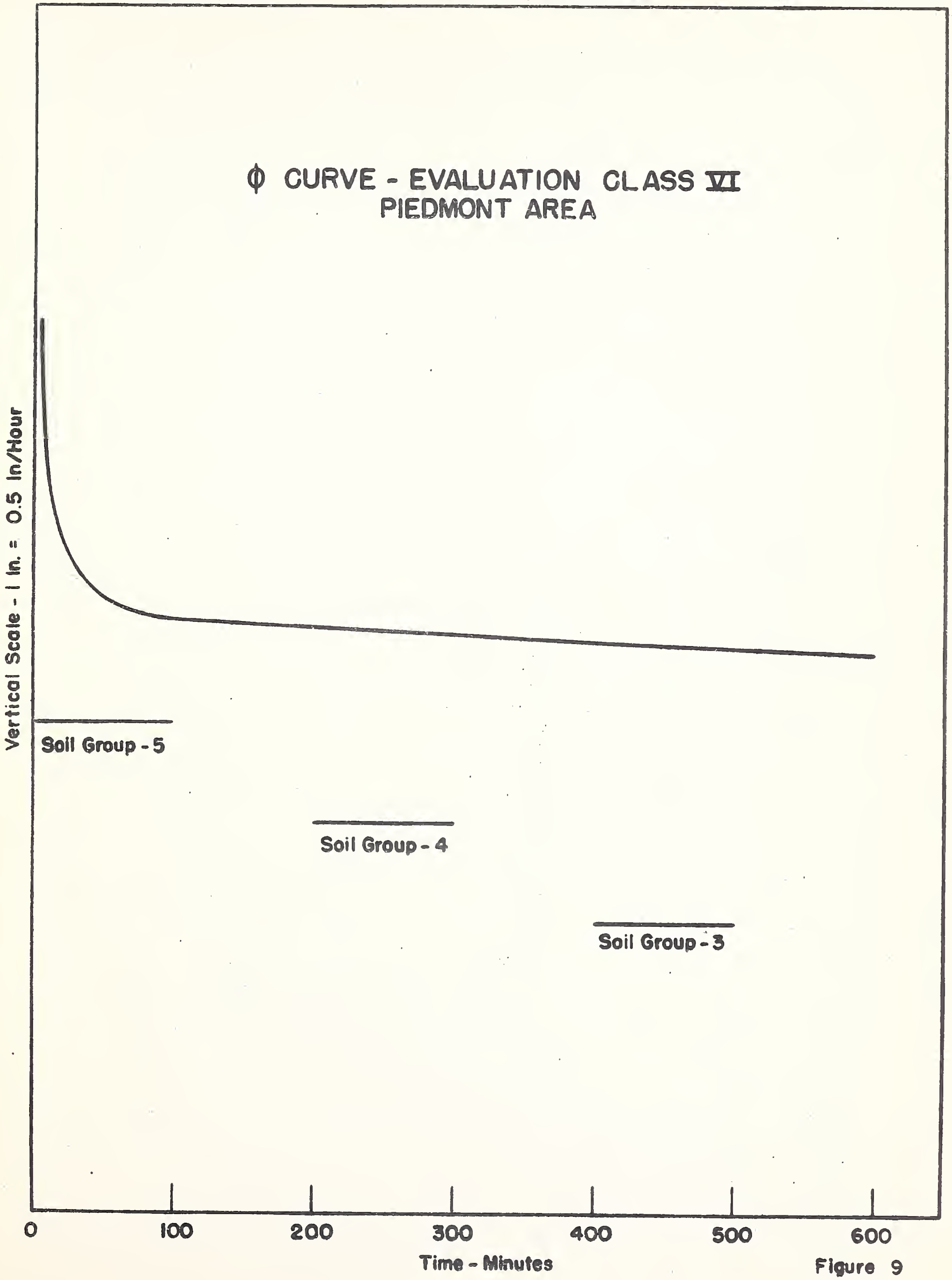

Φ CURVE - EVALUATION CLASS VI
PIEDMONT AREA
Vertical Scale - 1 In. = 0.5 In/Hour
Soil Group - 5
Soil Group - 4
Soil Group - 3
0
100
200
300
400
500
600
Time - Minutes

Figure 9

Coastal Plain - Assunpink Creek at Trenton, New Jersey.

- Maurice River at Norma, New Jersey.

Three additional samples in the Upland section cover a wide area range and were used to verify and extrapolate the findings from the principal samples.

A series of flood producing storms covering the range from minimum to maximum damage was composited for each of the nine sample subwatersheds. Published and unpublished records of precipitation amounts and intensities, furnished largely by the U. S. Weather Bureau, were used in determining the storm values. The procedure followed is described below and illustrated in figure 10.

<u>Relationship of Discharge (Q) to Runoff (Y)</u> - For each of the sample watersheds United States Geological Survey records of stream flow were utilized to determine the peak discharge and surface runoff for all important floods of record. For the latter determination, individual flood hydrographs were constructed on which were plotted curves of base flow assignable to ground water accretions. The area between the two curves was determined and its value in watershed area depth was plotted against the peak discharge. The curve showing the average relationship between peak discharge (designated Q) in second-feet and runoff (designated Y) in equivalent depth in inches over the watershed was drawn from the series of points so plotted.

<u>Relationship of Precipitation (P) to Runoff (Y)</u> - U. S. Weather Bureau records of daily and hourly amounts of precipitation were used to determine the rainfall contributing to the peak

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HYDROLOGIC RELATIONSHIPS
CHESTER CREEK WATERSHED, PA.

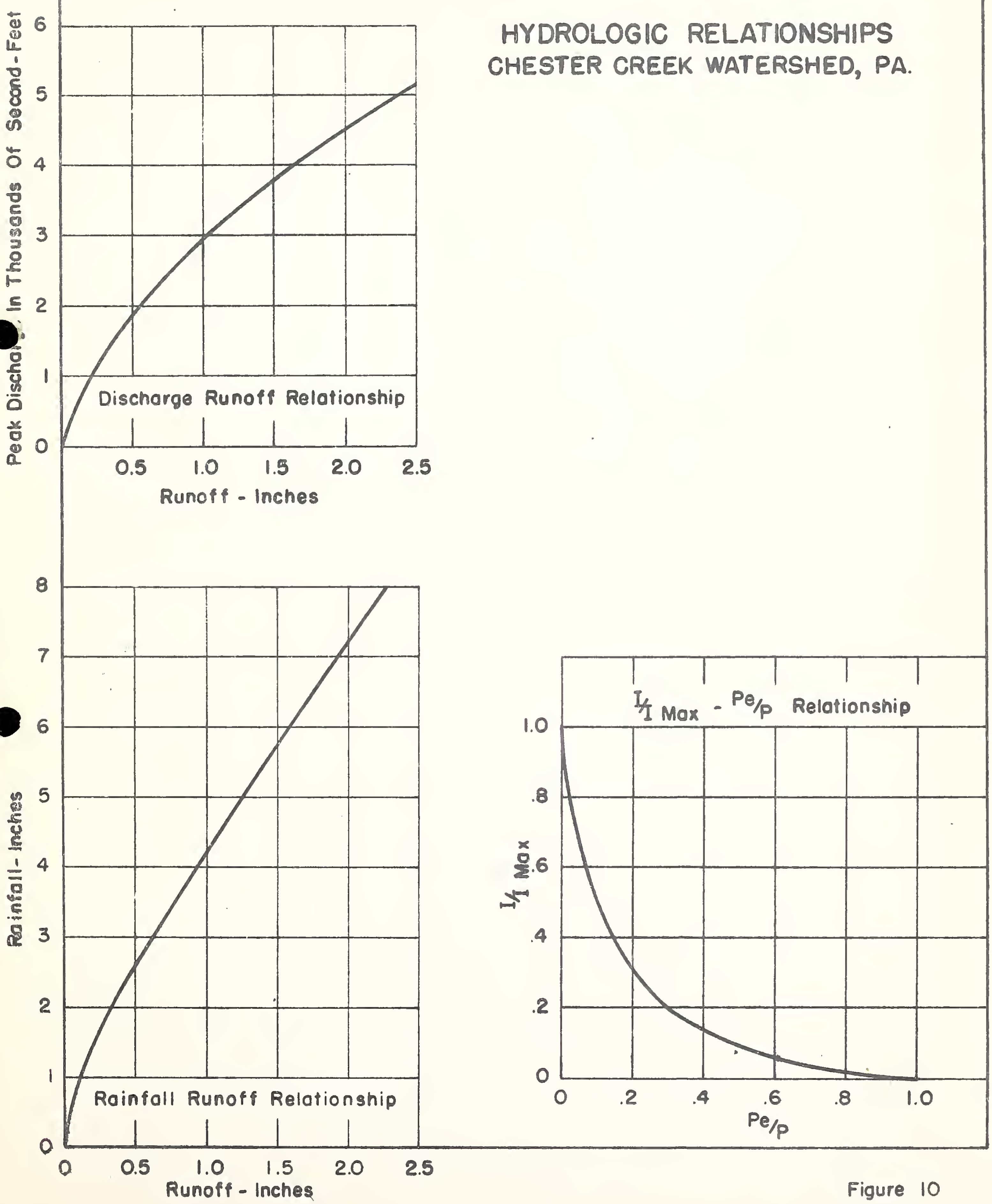

Figure 10

discharge. Rainfall at the stations in and immediately adjacent to the watershed was weighted by the Horton-Theissen method to determine the average inches depth on the watershed contributing to the flood crest. Precipitation so determined (designated P) was plotted against the corresponding runoff (Y) in the same unit of measure.

Relationship of Pe/P to I/I max - This relationship was determined from 5-minute intensity data of 44 storms at Binghamton, New York, in the following manner; the actual 5-minute intensities for each storm were arranged in descending order of magnitude. For each storm the individual 5-minute intensities (I) were each divided by the maximum 5-minute intensity (I max), and the corresponding Pe values (quantity of rainfall that fell at an equal or greater intensity) were each divided by the total storm rainfall (P), thus providing two sets of ratio values that were plotted I/I max against Pe/P. A curve indicating the average relationship was drawn resulting in a dimensionless diagram. The slope of this curve determined from its tangent at several representative points and expressed in units of abscissa over ordinate is designated N. This value is used in determining intensity--duration relationships during the storm.

The above relationships provided the basis for development of a series of storms correlating discharge, precipitation, runoff and maximum intensity. Maximum intensity for each of the storms was determined by analysis of many historical storms. For each of the storms a Pe curve and a storm intensity diagram were computed as shown in table 13 and plotted, figure 11. The Pe curve shows at each point the quantity of rain falling at a rate equal to or

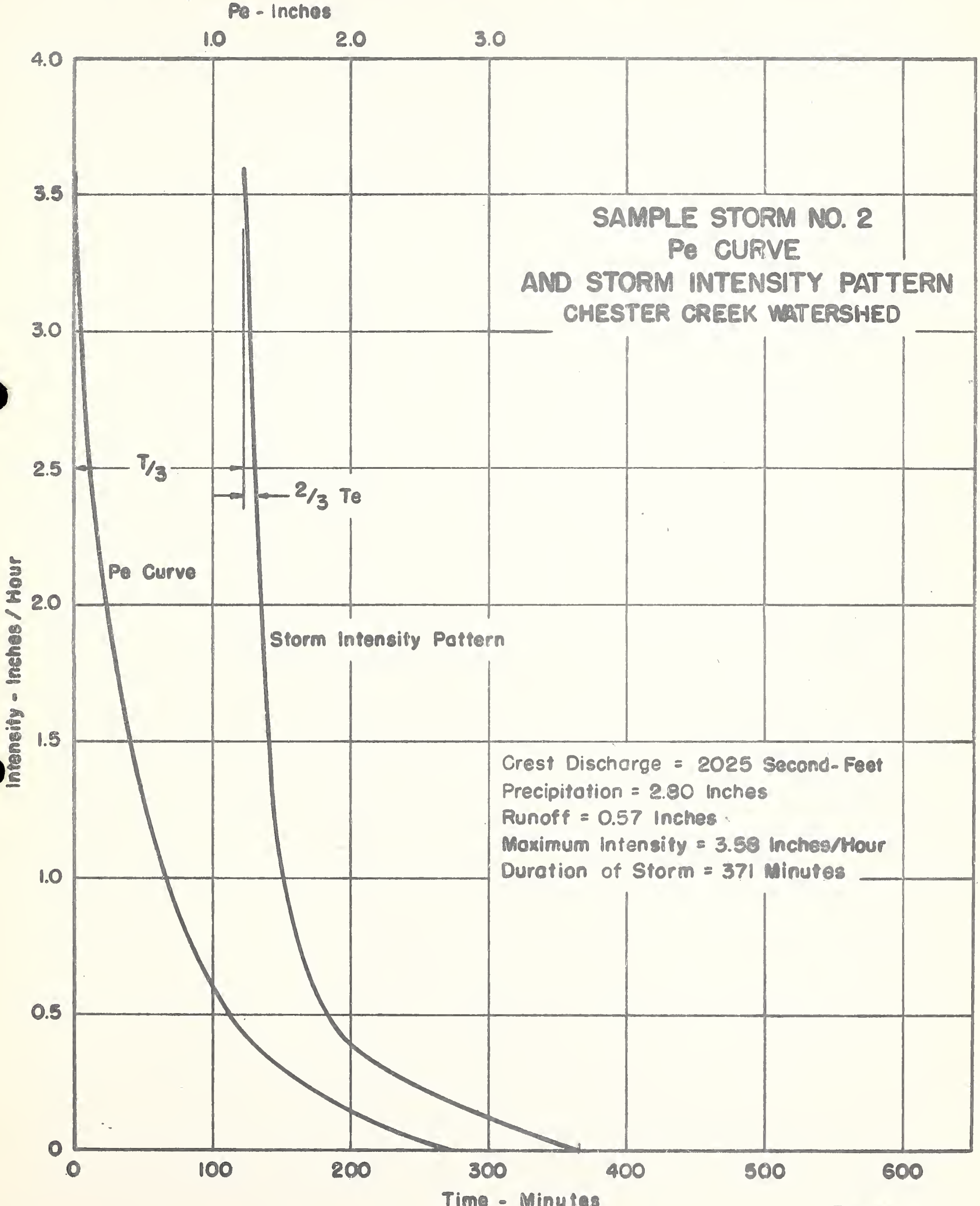
Pe - Inches
1.0
2.0
3.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
T/3
2/3 Te
Pe Curve
Storm Intensity Pattern
SAMPLE STORM NO. 2
Pe CURVE
AND STORM INTENSITY PATTERN
CHESTER CREEK WATERSHED
Crest Discharge = 2025 Second-Feet
Precipitation = 2.80 Inches
Runoff = 0.57 Inches
Maximum Intensity = 3.58 Inches/Hour
Duration of Storm = 371 Minutes
Intensity - Inches / Hour
0
100
200
300
400
500
600
Time - Minutes

Figure 11

Table 13. Pe - Storm Pattern Work Sheet

Delaware River Watershed

Sample Watershed of Chester Creek
near Chester, Pennsylvania

Storm No. 2

Q = 2,025 second ft. P = 2.80 inches I max = 3.58 in/hr. Y = 0.57 inches

T = 6.1788 hours = 371 minutes $\frac{T}{3}$ = 2.0599 hours $\frac{P}{I\ max}$ = .782123

$\frac{I}{I\ max}$	$\frac{Pe}{P}$	N	I	Pe	Te	$\frac{2Te}{3}$	$\frac{T}{3} + \frac{2Te}{3}$ (hours)	$\frac{T}{3} + \frac{2Te}{3}$ (minutes)
1.0	0	0	3.58	0	0	0	2.0599	124
0.9	.006	.111	3.22	.017	.0868	.0579	2.1178	127
0.8	.021	.168	2.86	.059	.1314	.0876	2.1475	129
0.7	.042	.231	2.51	.118	.1807	.1205	2.1804	131
0.6	.067	.305	2.15	.188	.2385	.1590	2.2189	133
0.5	.104	.408	1.79	.291	.3191	.2127	2.2726	136
0.4	.152	.571	1.43	.426	.4466	.2977	2.3576	141
0.3	.220	.800	1.07	.616	.6257	.4171	2.4770	149
0.2	.315	1.411	.72	.882	1.1036	.7357	2.7956	166
0.1	.480	2.641	.36	1.344	2.0656	1.3771	3.4370	206
0.05	.665	4.860	.18	1.862	3.8011	2.5341	4.5940	276
0.00	1.000	7.900	0.00	2.800	6.1788	4.1192	6.1791	371

greater than the corresponding intensity, a quantity sometimes called "excess precipitation." The time on the storm pattern for any intensity shows the length of time for which an equal or greater intensity prevailed during the storm. The time values are designated by the symbol Te (duration of time of excess).

Storm No. 2 for Chester Creek produces a peak discharge of 2,025 second-feet as shown in table 13. Based on this peak discharge, the corresponding values of Y, P, and I max were determined from the above-described relationships. From the discharge-runoff relationship a peak discharge of 2,025 second-feet accompanies 0.57 inches of runoff; from the P-Y curve, 0.57 inches of runoff is derived from 2.80 inches of rainfall; an analysis of selected storms shows that 2.80 inches of rainfall has a maximum intensity of 3.58 inches per hour. From the I/I max-Pe/P curve, the values of Pe/P were taken to correspond with each of the selected values of I/I max. (table 13). Both table 13 and figure 11 show that the total rainfall of 2.80 inches fell during a period of 371 minutes.

The Pe and Te diagrams, in conjunction with the ∅ curves for the several evaluation classes make possible the evaluation of the recommended land conversion phase of the program. To obtain the Pe value for each class and soil group, the ∅ curve was superimposed upon the storm pattern so that the base lines coincided and the zero time line of the ∅ curve was positioned on such a time line that computed runoff agreed with measured. The Pe values for a given evaluation class were found on the Pe scale horizontally opposite to the point of intersection of the ∅ curve and Te curve. Multiplying this Pe value by the percent of the tributary area in that evaluation class (table 14) gave a runoff value for that class.

Table 14. Runoff Reduction Determination - Evaluation Class Conversion

Delaware River Watershed

Chester Creek Watershed at Chester, Pa. D.A. 61.1 Sq.Mi.

Storm Number 2 P = 2.80 in. Y = 0.57 in.

Coincidence at 105 min. Qp = 2,025 sec.-ft.

Soil Group	Evaluation Class	Present Conditions			Recommended Program	
		Area %	Pe	% In.	Change in Area %	Change in % In.
3	I	3.4	.03	0.10	5.0	0.15
	II	4.5	.14	0.63	(-) 2.7	(-) 0.38
	III	2.1	.22	0.46	(-) 1.6	(-) 0.35
	IV	8.8	.26	2.29	7.8	2.03
	V	33.9	.40	13.56	(-) 9.2	(-) 3.68
	VI	7.5	.53	3.98	0.7	0.37
4	I	1.2	.14	0.17	2.8	0.39
	II	1.6	.29	0.46	(-) 0.8	(-) 0.23
	III	0.7	.40	0.28	(-) 0.5	(-) 0.20
	IV	3.3	.48	1.58	4.5	2.16
	V	14.3	.64	9.15	(-) 5.2	(-) 3.33
	VI	3.1	.82	2.54	(-) 0.8	(-) 0.66
5	I	1.5	.37	0.56	1.9	0.70
	II	1.9	.53	1.01	(-) 1.1	(-) 0.58
	III	0.9	.67	0.60	(-) 0.7	(-) 0.47
	IV	0.8	.85	0.68	0.8	0.68
	V	3.7	1.09	4.03	(-) 0.8	(-) 0.87
	VI	0.8	1.33	1.07	(-) 0.1	(-) 0.13
	Other	6.0	2.38	14.28	0.0	0.0
	TOTALS	100.0		57.43		(-) 4.40

Table 14. (Cont.) Runoff Reduction Determination

Effect of changes in evaluation classes - $\frac{4.40}{57.43}$ = 7.66% reduction

Effect of increased humus on detention storage:

Evaluation Class	Average inches humus depth	% Area Change	Depth-% Area Change
I	2.87	9.7	27.84
II	1.58	(-) 4.6	(-) 7.27
III	0.73	(-) 2.8	(-) 2.04
TOTAL			18.53

Total Depth-% Area Increase = 18.53 x .05" (detention storage of increased humus) = 0.93% inches

Effect of contour measures on detention storage:

12.1% area x .05" = .60% in.

Summary:

	Storage (% inches)	Runoff (% inches)
Present condition of runoff		57.43
Effect of changes in evaluation classes	4.40	53.03
Effect of increased woodland humus on detention storage	.93	52.10
Effect of contour measures on detention storage	0.60	51.50

Total effect of recommended land treatment program:

$\frac{57.43 - 51.50}{57.43}$ = 10.33% Reduction in Volume Runoff

The summation of these values for all the classes in the sample watershed gives the total computed runoff. Table 14 illustrates this calculation for storm No. 2 on Chester Creek. The computed runoff agreed very closely with the measured runoff.

The Pe values were then multiplied by the corresponding recommended percent of area in each evaluation class, and the products added to determine the runoff under recommended conditions. By comparing the computed runoff from the present program with the changes in future computed runoff, the percent reduction in peak flow that would result from the land use changes of the recommended program was found.

Additional detention storage due to program measures was conservatively accounted for on the basis of .05 inch per inch of estimated additional humus accumulation in woodlands and .05 inch depth for openland acreage to be placed under contour tillage. From the above calculations for storm No. 2 on Chester Creek, the recommended program would result in a total of 10.33 percent reduction in peak discharge (figure 12 and table 14).

From the sample tributary analysis, a generalized series of percent reduction - drainage area - frequency curves was drawn for each of the three physiographic sections. These curves provided the basis for determining for each subwatershed the percent reductions in peak discharge and associated reduction in damage due to inundation by flood flows (figures 13, 14 and 15).

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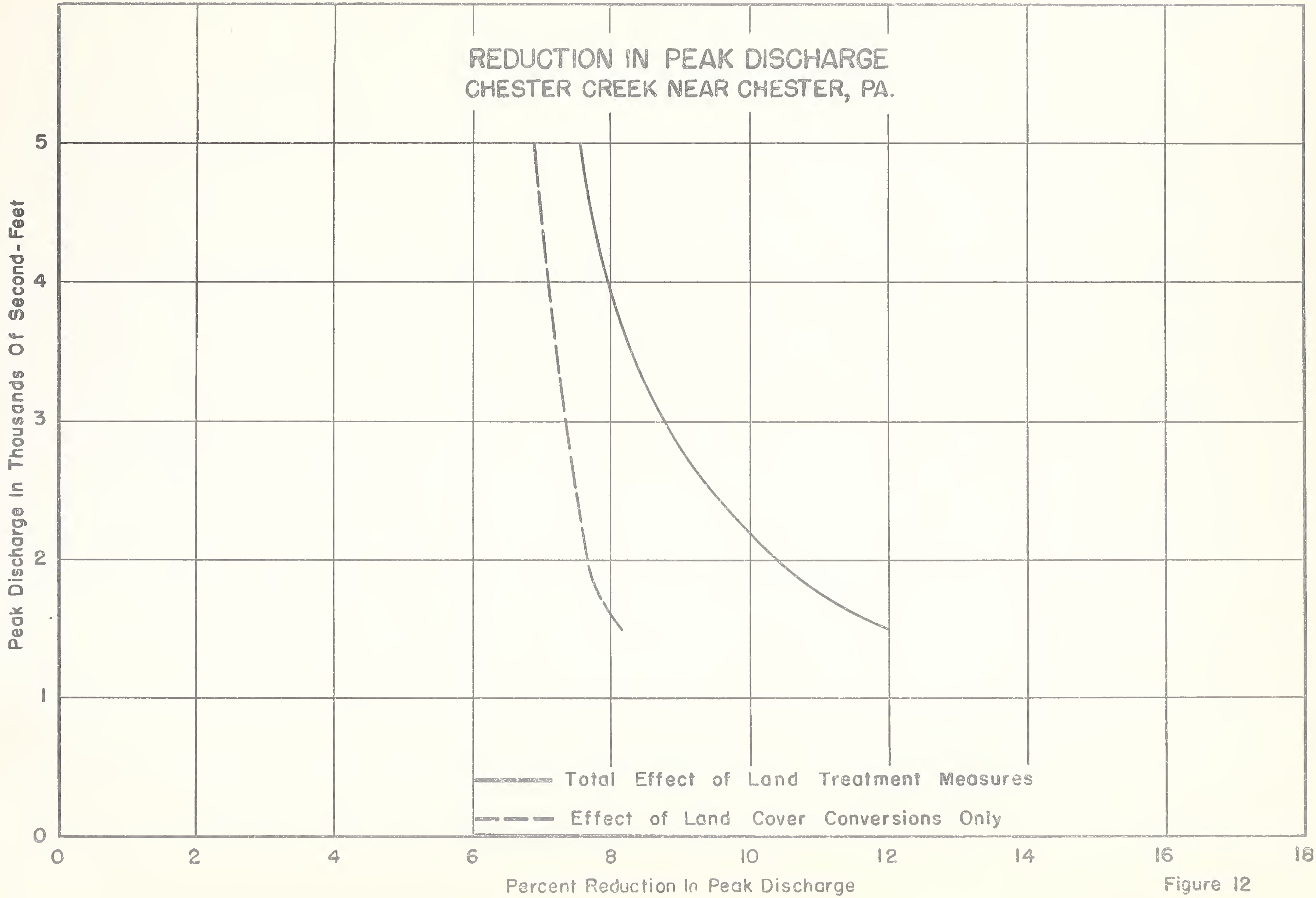

Figure 12

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DELAWARE RIVER WATERSHED
DELAWARE, NEW JERSEY, NEW YORK, PENNSYLVANIA

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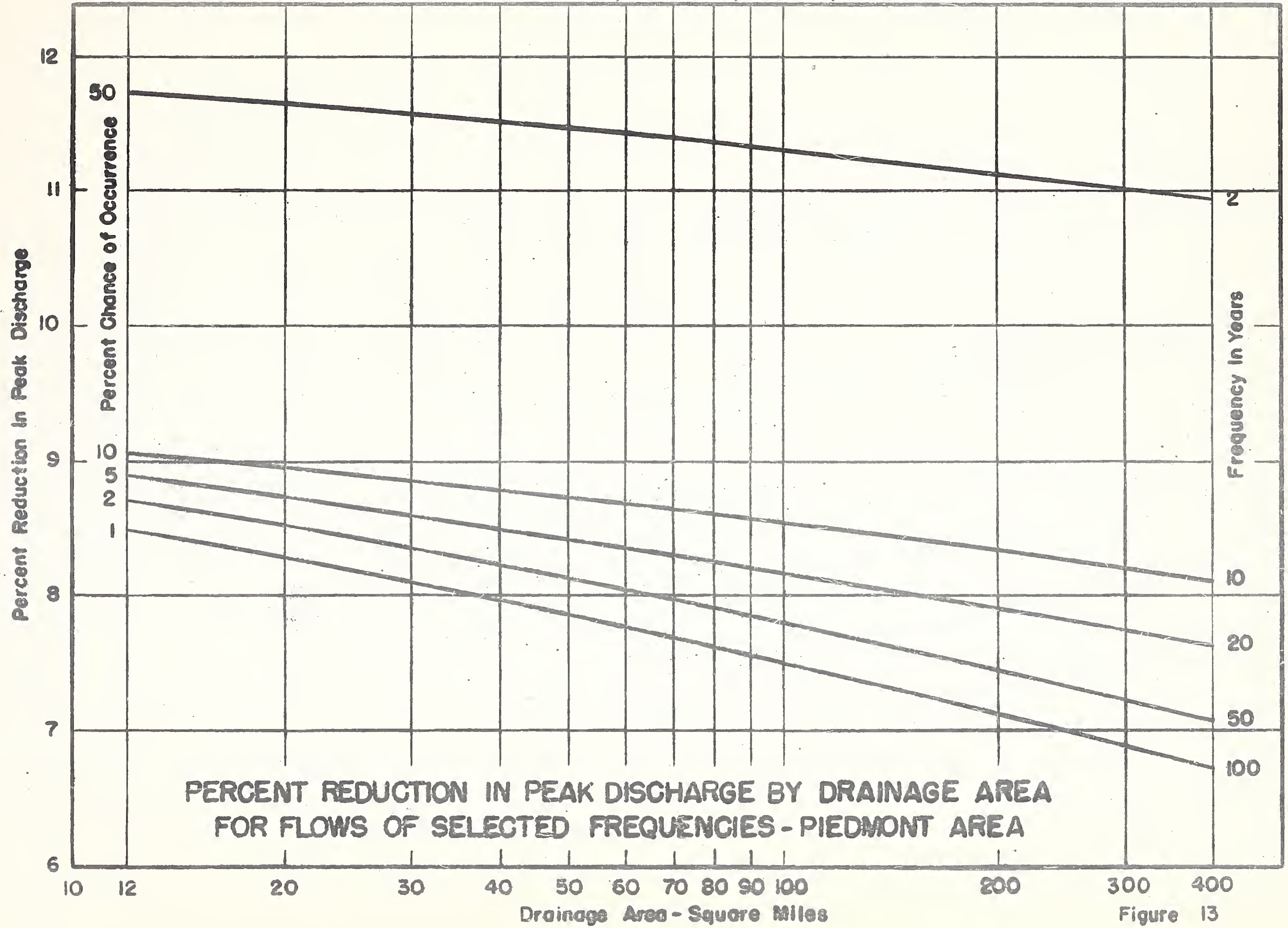

PERCENT REDUCTION IN PEAK DISCHARGE BY DRAINAGE AREA
FOR FLOWS OF SELECTED FREQUENCIES - PIEDMONT AREA

Figure 13

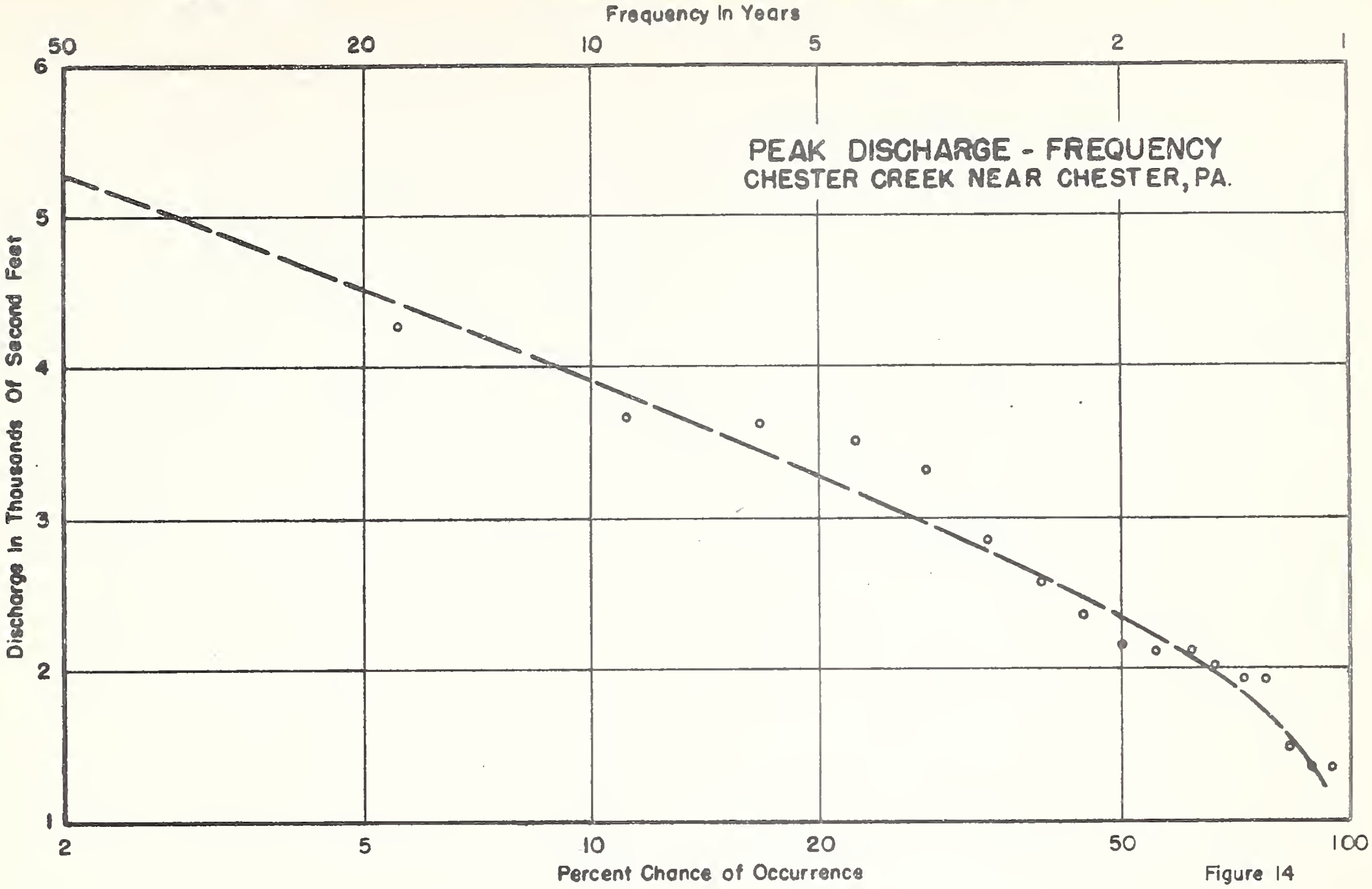

Figure 14

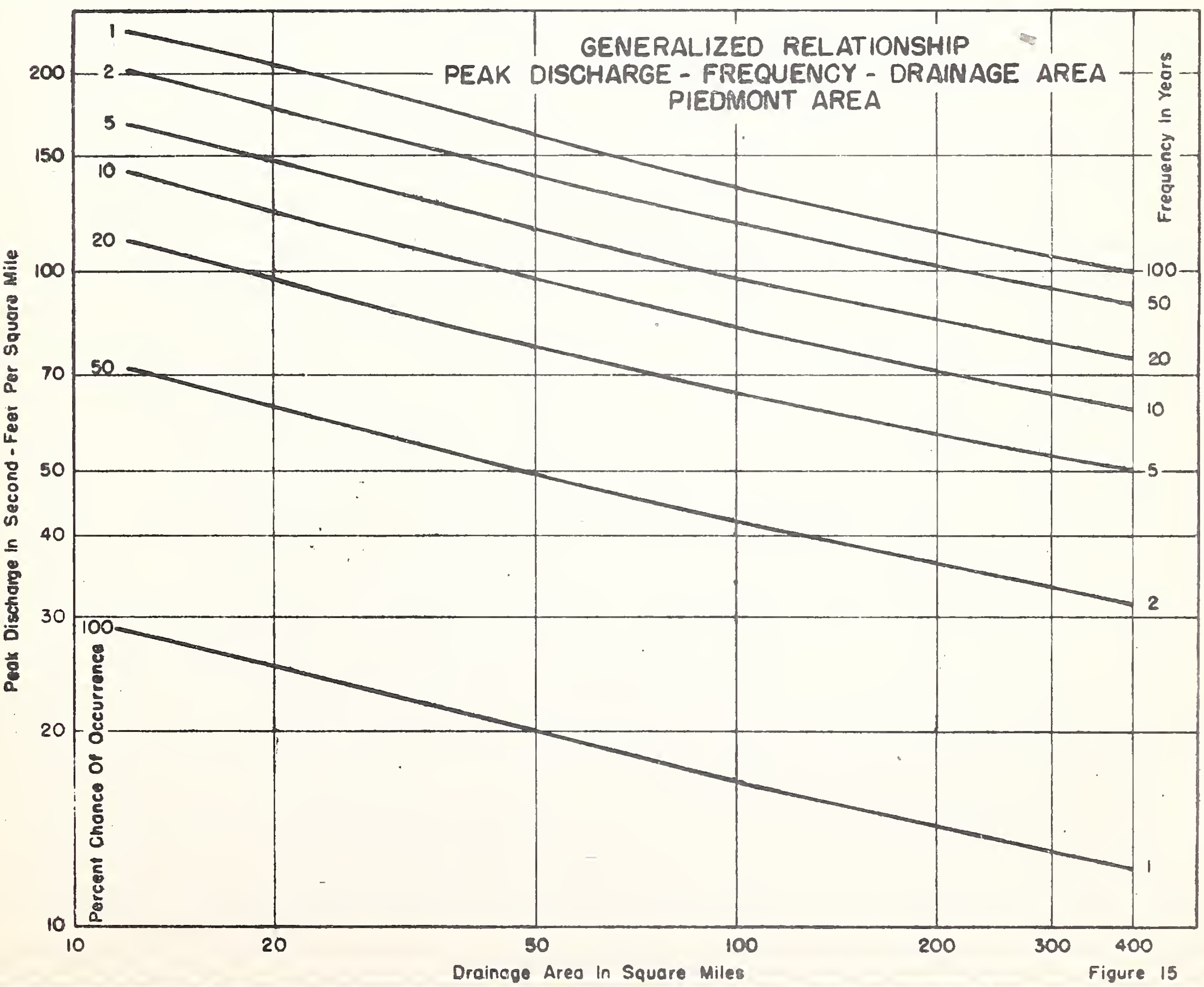

Figure 15

Reduction in Sedimentation

It is estimated the present rate of sedimentation damage on the watershed will be reduced at least 70 percent by the recommended program. The degree of erosion control attained will depend on such factors as type of soil, type of agriculture, and nature of topography. For some fields the erosion rate can be reduced by 95 percent, while for other 60 percent may be the maximum reduction attainable.

The production of sediment will be decreased as a result of retirement of steep cropland to woodland or pasture, improved rotations, and installation of erosion control practices and measures.

Sediment damage to highways resulting from openland erosion will be subject to an estimated 80 percent reduction. Sources of such damage are usually local and the remedy for a particular damage point frequently involves but one or, at the most, a few farms.

Additional Measures

Stream Channel Improvement

This measure provides for the excavation, realignment and bank sloping of stream channels to increase the capacity and reduce the frequency of out-of-bank flow. An example of the effect of this type of measure on flood damage is illustrated by 1,000 feet of channel improvement planned on Elk Creek, one of the sample tributaries studies.

The channel was designed with a capacity to accommodate a flow of 5-year frequency, and by using the methods shown in Appendix VI

would result in a reduction of 50 percent of the annual residual damage after the land treatment and a corresponding annual benefit of $57.50.

The estimated installation cost, including construction, engineering, and easements, amounts to $650, of which $475 is public and $175 private. Expressed in annual terms, using $2\frac{1}{2}$ and 4 percent rates of interest respectively, the cost is $18.87. It is estimated that the annual maintenance cost will be $20.00, making a total annual cost of $38.87.

The benefit-cost ratio of this particular stream channel improvement is 1.5 to 1.

Flood Water Retarding Structures

To determine the physical effect of the structures tentatively selected for inclusion in the recommended program (see Appendix III, Needs of the Watershed), a field study of the sample sites was necessary. From this study the type of structure, height, earth fill and storage capacity were estimated and, by applying unit costs, an estimate of the installation cost of the structure was made. Using the formula $\left(\frac{\text{Uncontrolled Drainage Area}}{\text{Total Drainage Area}}\right)^{\frac{1}{2}}$ x Estimated Discharge = Modified Discharge, it was possible to estimate the reduction in discharge to be expected at any damage reach below the structure. "Total drainage area", in the formula, is the drainage area above the damage reach, while "uncontrolled drainage area" is that part of the total drainage area not affected by the structure. "Estimated discharge", in the formula, was the discharge resulting under conditions prevailing with the recommended land treatment practices.

An example of the effect of this type of measure is illustrated by a particular site on Read Creek. The total drainage area is 5.0 square miles while the drainage area above the structure is 2.0 square miles. Application of the formula gives a 22 percent reduction in discharge, and by using the methods shown in Appendix VI the annual benefit is \$200.00.

The estimated installation cost amounts to \$6,500, of which \$4,500 is Federal and \$2,000 other public. Expressed in annual terms, using a $2\frac{1}{2}$ percent interest rate, the cost is \$162.50. The expected annual maintenance cost is \$25.00, making a total annual cost of \$187.50.

A comparison of the above figures shows that the benefit-cost ratio of this structure is 1.1 to 1.

Diking

This measure is recommended where the present channel condition and capacity are inadequate and limitations of gradient and right-of-way prohibit excavation to the required capacity. The effect of diking is to contain within floodways the flow which would normally be outside of the existing channel. An example of the computation of the effect of this measure on Stewart Brook, one of the sample tributaries, follows:

Construction of 300 feet of 3-foot dike would provide a floodway with a discharge capacity equal to the discharge to be expected once in approximately 35 years. By using the methods shown in Appendix VI, the estimated annual benefits for this diking will be \$52.05.

The estimated installation cost of this 300-feet of dike is \$318, of which \$268 is public and \$50 is private. Expressed in annual terms, using $2\frac{1}{2}$ and 4 percent rates of interest respectively, the cost is \$8.70. It is estimated that the annual maintenance cost will be \$17.00, making a total annual cost of \$25.70.

The benefit-cost ratio of this particular section of diking is 2 to 1.

V. COST OF THE RECOMMENDED PROGRAM

Costs of the recommended program account for all expenditures required to install, maintain or operate the remedial measures. Materials and equipment supplied by the landowners or operators and unpaid family labor are included as program costs. Costs of operating farmer-owned equipment were considered as the costs involved for the additional use of the equipment. Maintenance and operation of the measures are computed in terms of annual costs.

Land Treatment Measures and Practices

Costs of specific measures were determined by applying unit costs of the measures to the number of units to be installed in the watershed. The unit costs of measures were determined by application of 1949 costs of labor, equipment and materials to the average quantity and types of labor, equipment and materials required. These costs are shown in table 15. Soil Conservation Service and Forest Service records of operations were used in determining quantities and types required. Supplementary data were obtained from other federal, state, and local agencies.

Educational costs are based on an estimate made from information supplied by the Extension Service in the states in the watershed.

The installation costs of the recommended measures include the cost of educational assistance, technical services, and the

Table 15. Basic Cost (1949) Used in Computing Practice Costs
Delaware River Watershed

Item	Unit	Cost Per Unit
		(dollars)
Farm Labor	Hour	0.80
Farm Tractor	Hour	0.65
Farm Truck	Hour	0.50
45 H.P. Tractor and Operator	Hour	8.50
Motorized Grader and Operator	Hour	8.10
Fertilizer (Multiflora Rose)	100#	2.50
Fertilizer (Other Practices)	100#	2.00
Lime	Ton	7.00
Ryegrass Seed	Pound	0.163
Grass Seed (Average of Several Varieties)	Pound	0.50
Fence Posts	Each	0.50
Barbed Wire	Rod	0.10
Multiflora Rose	1000 Plants	8.00
Shrubs (Wildlife Borders)	1000 Plants	8.00
Concrete (Formed)	Cu.Yd.	60.00

cost of short term evaluations and studies of the effects of the measures. These costs were computed separately and then combined with costs of labor, equipment and materials for the individual measures.

The total installation cost of the land treatment measures and practices is approximately $72,851,000. Of this cost the Federal Government will bear approximately 13.3 percent for technical services; 2.8 percent for administration of direct aids; 1.8 percent for educational assistance; 1 percent for testing and evaluation of measures; and 28.4 percent for direct aids, special equipment and materials. Non-federal public agencies will bear approximately 5.4 percent for technical services; 1.8 percent for educational assistance; 3.3 percent for installation of the land treatment program on non-federal public lands; and 1.7 percent for materials. Private interests will bear approximately 40.5 percent for installation of the land treatment program on privately owned lands.

The installation costs of the measures and practices will be borne by the Federal Government, non-federal public agencies, and private landowners and operators, as shown in table 16.

Maintenance and operation costs of the land treatment measures and practices were computed by applying unit costs of maintenance and operation to the quantities of the measures to be installed. The unit costs were developed in a manner similar to that used for installation costs. The maintenance and operation cost reflects the additional cost of farm operations.

Table 16. Quantities and Distribution of Installation and Annual Operation and Maintenance Costs 1/ of the Recommended Program
Delaware River Watershed

Measure	Unit	Quantity	Installation Costs				Annual Operation and Maintenance Costs			
			Federal	Non-Federal Public 2/	Non-Federal Private	Total	Federal	Non-Federal Public 2/	Non-Federal Private	Total
			(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Land Treatment Measures										
1. Contour Strip Cropping	Acres	870,000	2,408,000	94,000	1,841,000	4,343,000			10,000	10,000
2. Cover Cropping	Acres	118,400	264,000	29,000	1,364,000	1,657,000			505,000	505,000
3. Diversions and Terraces	Miles	3,040	1,019,000	30,000	229,000	1,278,000			10,000	10,000
4. Outlets and Waterways	Acres	6,480	2,739,000	79,000	213,000	3,031,000			102,000	102,000
5. Establishing Perennial Hay	Acres	281,430	5,800,000	233,000	7,459,000	13,492,000			5,026,000	5,026,000
6. Pasture Management	Acres	685,900	2,443,000	162,000	6,431,000	9,036,000			726,000	726,000
7. Contour Furrowing	Acres	147,100	1,866,000	41,000	349,000	2,256,000			349,000	349,000
8. Streambank Erosion Control	Miles	275	2,904,000	73,000	1,181,000	4,158,000			186,000	186,000
9. Erosion Control Structures	Number	9,800	4,179,000	117,000	706,000	5,002,000			24,000	24,000
10. Woodland Management	Acres	3,976,600	7,612,000	4,855,000	7,577,000	20,044,000	282,000	329,000	417,000	1,028,000
11. Tree and Shrub Planting	Acres	256,600	3,253,000	1,477,000	2,182,000	6,912,000	-	-	-	-
12. Land Acquisition	Acres	167,600	17,000	1,625,000	-	1,642,000	-	-	-	-
Subtotal I			34,504,000	8,815,000	29,532,000	72,851,000	282,000	329,000	7,355,000	7,966,000
Additional Measures										
1. Stream Channel Improvement	Miles	423	2,260,000	183,000	381,000	2,824,000	-	44,000	58,000	102,000
2. Water Retarding Structure	Number	133	1,071,000	217,000	55,000	1,343,000	-	20,000	1,000	21,000
3. Diking	Miles	17	69,000	4,000	9,000	82,000	-	2,000	1,000	3,000
Subtotal II			3,400,000	404,000	445,000	4,249,000	-	66,000	60,000	126,000
TOTAL			37,904,000 3/	9,219,000 4/	29,977,000	77,100,000	282,000 5/	395,000	7,415,000	8,092,000

1/ Based on 1949 prices
2/ State and local governments, their departments and agencies.
3/ Includes technical service, educational assistance, and hydrologic evaluations.
4/ Includes technical service and educational assistance.
5/ Technical services.

Of the $7,966,000 cost of annual maintenance and operation of the land treatment measures and practices, $7,355,000 or its equivalent will be expended by private landowners and operators. The Federal Government will bear $282,000 and other public agencies will bear the remaining $329,000. A further breakdown of annual maintenance costs is shown in table 16.

The total cost of public acquisition of approximately 167,600 acres of land, based on an estimated average cost of $9.80 per acre is $1,642,000. The cost of installing and maintaining woodland improvement and management measures on this land is included in table 16.

It is expected that Federal and non-federal public interests will bear the cost of acquisition, and the cost of necessary improvement and management measures.

Additional Measures

Stream Channel Improvement

Estimated installation costs of approximately 423 miles of stream channel improvement with the necessary lateral drainage, for prevention of damages associated with overflow and sedimentation are as follows:

Item	Federal Cost	Non-federal Cost		Total Cost
		Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)
Construction Costs	1,835,000	143,000	277,000	2,255,000
Easements and Rights-of-way, etc.		20,000	91,000	111,000
Engineering, Supervision, etc.	196,000	12,000		208,000
Contingency	229,000	8,000	13,000	250,000
TOTAL	2,260,000	183,000	381,000	2,824,000

The estimated average annual maintenance and operation cost of this measure is $102,000. It is expected that this will be borne by local interests and will be administered by a local agency or agencies acceptable to the Secretary of Agriculture.

Water Retarding Structures

Estimated installation costs of 133 water retarding structures are as follows:

Item	Federal Cost	Non-federal Cost		Total Cost
		Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)
Construction Costs	829,000	20,500	27,500	877,000
Easements and Rights-of-way, etc.		193,500	27,500	221,000
Engineering, Supervision, etc.	149,000	3,000		152,000
Contingency	93,000			93,000
TOTAL	1,071,000	217,000	55,000	1,343,000

To determine maintenance costs on the larger structures, it was estimated that complete replacement of certain appurtenances would be necessary every 100 years at a cost of $283,640; therefore, $656 is included in the annual maintenance cost for the establishment of a sinking fund for this item. To determine maintenance costs on the remaining smaller structures, it was estimated that the probable chance of failure would be 1 percent in any one year (design frequency 100 years); therefore, 1 percent of the construction cost is included in the annual maintenance cost for this item. No estimate was made of the probable chance of failure on the larger structures because of the safety factor used in the design. In addition, normal maintenance costs have been included for such items as mowing, site maintenance, and minor repairs. The average annual maintenance cost is estimated to be $21,000. It is expected that state or local governments will bear $20,000 of this annual maintenance and that the remainder will be borne by landowners and operators. It is also

expected that the total amount will be administered by a local agency or agencies acceptable to the Secretary of Agriculture.

Diking

Estimated installation cost of approximately 17 miles of diking are as follows:

Item	Federal Cost	Non-federal Cost		Total Cost
		Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)
Construction Costs	55,000	500	3,500	59,000
Easements and Rights-of-way, etc.		3,500	5,500	9,000
Engineering, Supervision, etc.	10,000			10,000
Contingency	4,000			4,000
TOTAL	69,000	4,000	9,000	82,000

The average annual maintenance cost is estimated to be $3,000 which includes an amount for replacement every 50 years. It is expected that the total maintenance costs will be borne by local interests and will be administered by a local agency or agencies acceptable to the Secretary of Agriculture.

VI. BENEFITS OF THE RECOMMENDED PROGRAM

The primary effects of the recommended program toward reducing flood damage, sediment damage, and erosion damage were evaluated separately in monetary terms. Other benefits, monetarily evaluated, were increases in income and decreases in cost to landowners and operators due to the recommended changes in land management.

It is expected that when the recommended program is fully effective, the reduction in flood damages will be 48 percent and sediment damages 63 percent. Other benefits due to decreasing the hazards of floods and sedimentation, but not expressed in monetary terms, are savings in lives and mental distress, increase in property values, decrease in loss of fish and wildlife, increased low water flow of streams resulting in pollution abatement, water conservation, fewer interruptions in community functions, and others of more or less intangible nature.

Changes in land use and management, as recommended, will increase cropland and woodland production. They will also substantially control erosion which, in turn, will maintain present rates of production and/or decrease costs of production. These benefits, to the extent that they accrue to the landowners and operators, have been evaluated in monetary terms. From these private benefits, however, the public will gain by way of maintenance of natural resources and public revenues, a constant supply of cropland and woodland products, improved recreational facilities, and increases in wildlife throughout the watershed.

Reduction in Flood Damage

Benefits resulting from reductions in flood damages were derived separately for each stream where damages were evaluated. A summary of average annual flood damages and flood benefits is shown in table 17. The benefit is equivalent to the difference in average annual damage sustained under watershed conditions without the recommended program and the average annual damages to be expected with conditions prevailing under the recommended program. The benefits of the recommended land treatment measures and of the "additional measures" were computed separately. Benefits of the latter group were computed as the additional reduction in flood damages after applying the land treatment measures. The evaluated damages shown do not include those which are expected to be controlled by authorized programs of the Department of the Army, Corps of Engineers, or current activities of other Federal or state agencies. The benefits were computed accordingly. The method used in deriving flood damage reductions is illustrated by the following discussion of its application to Mauch Chunk Creek, a tributary of the Lehigh River.

Mauch Chunk Creek - Mauch Chunk Creek has a drainage area of approximately 8.9 square miles and flows into the Lehigh River at Mauch Chunk. Practically all of the damage caused by the creek occurs in the city of Mauch Chunk. The creek has an openwalled channel as it enters the city and from this point to its mouth it is confined to a covered channel under the streets

Table 17. Average Annual Flood Damages and Benefits
Delaware River Watershed
(1949 Prices)

Tributaries	Average Annual Damage With			Flood Damage Reduction From		
	Going Program	Land Treatment	Additional Measures 1/	Land Treatment	Additional Measures 2/	Total
	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
West Branch Delaware	18,600	16,150	16,150	2,450	-	2,450
East Branch Delaware	17,300	14,440	11,200	2,860	3,240	6,100
McMichaels Creek	800	560	560	240	-	240
Cherry Creek	800	640	640	160	-	160
Pequest River	238,200	238,200	-	-	238,200	238,200
Bushkill Creek	35,300	23,760	13,320	11,540	10,440	21,980
Lehigh River	239,200	186,880	138,910	52,320	47,970	100,290
Lopatcong Creek	15,500	9,620	2,140	5,880	7,480	13,360
Tohickon Creek	700	620	620	80	-	80
Neshaminy Creek	2,300	1,720	1,720	580	-	580
Schuylkill River	216,800	159,540	159,540	57,260	-	57,260
Chester Creek	41,800	31,040	25,620	10,760	5,420	16,180
Brandywine Creek	21,200	16,540	16,540	4,660	-	4,660
Red Clay Creek	8,100	5,410	4,190	2,690	1,220	3,910
White Clay Creek	1,100	980	980	120	-	120
Coastal Plain Tributaries	54,900	41,320	41,320	13,580	-	13,580
Miscellaneous Upland Tributaries	148,700	121,480	100,030	27,220	21,450	48,670
Miscellaneous Piedmont Tributaries	591,400	508,150	322,780	83,250	185,370	268,620
TOTAL	1,652,700	1,377,050	856,260	275,650	520,790	796,440

1/ The damage values account for effect of additional measures in combination with land treatment.

2/ These values include only the incremental reductions effected by additional measures.

and buildings. Several damaging floods have occurred in Mauch Chunk among which were those in 1942, 1933, 1928, 1926, 1862, and 1841. Associated with floods, there have been several lives lost and serious disruptions of community functions.

Damage frequency relations, representing watershed conditions respectively prevailing without and with the recommended program, are shown by three graphs in figure 16. The upper graph shows the damage frequency relations representing watershed conditions without the recommended program; the graph immediately below it shows this relationship for conditions prevailing with the land treatment phase of the recommended program, and the lowest graph illustrates the damage frequency for conditions prevailing with the combined program of land treatment and a water retarding structure. These graphs, indicating damage-frequency relations, were developed by means of substituting flood damage for discharge in the graphs of discharge-frequency relations, shown in figure 17. The method of deriving the latter graphs is illustrated in Appendix IV.

The benefits are computed from the graphs in figure 16. The average annual damages without the recommended program are $13,390, with the recommended land treatment measures $11,620, and with the total recommended program $3,600. Hence, the benefit of the recommended land treatment measures is $1,770 and the benefit of the additional measure is $8,020 or a total of $9,790.

Land Enhancement - In many low gradient streams, where frequent flooding occurs, the bottomland is used less intensively

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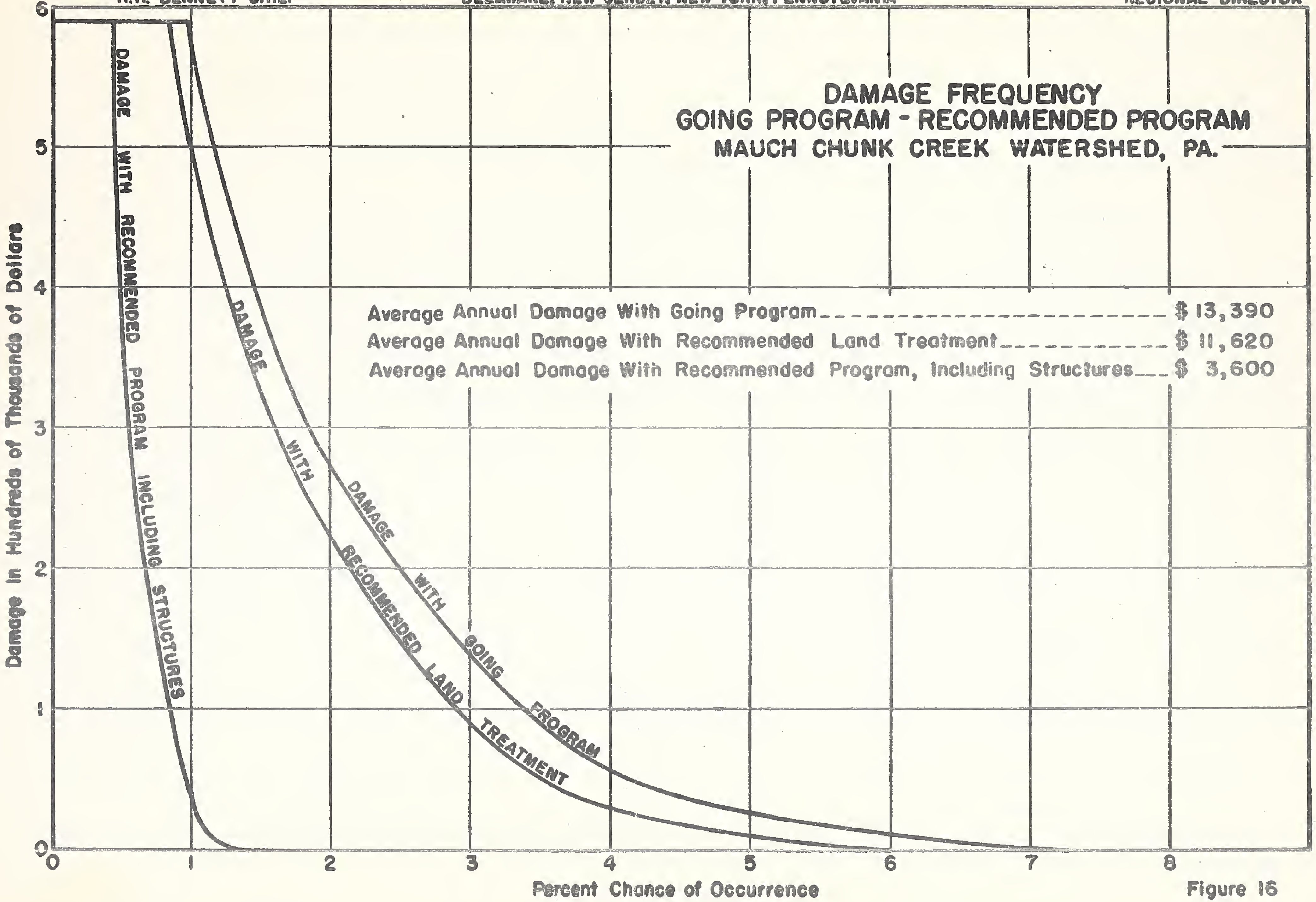

Figure 16

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. BENNETT, CHIEF

DELAWARE RIVER WATERSHED
DELAWARE, NEW JERSEY, NEW YORK, PENNSYLVANIA

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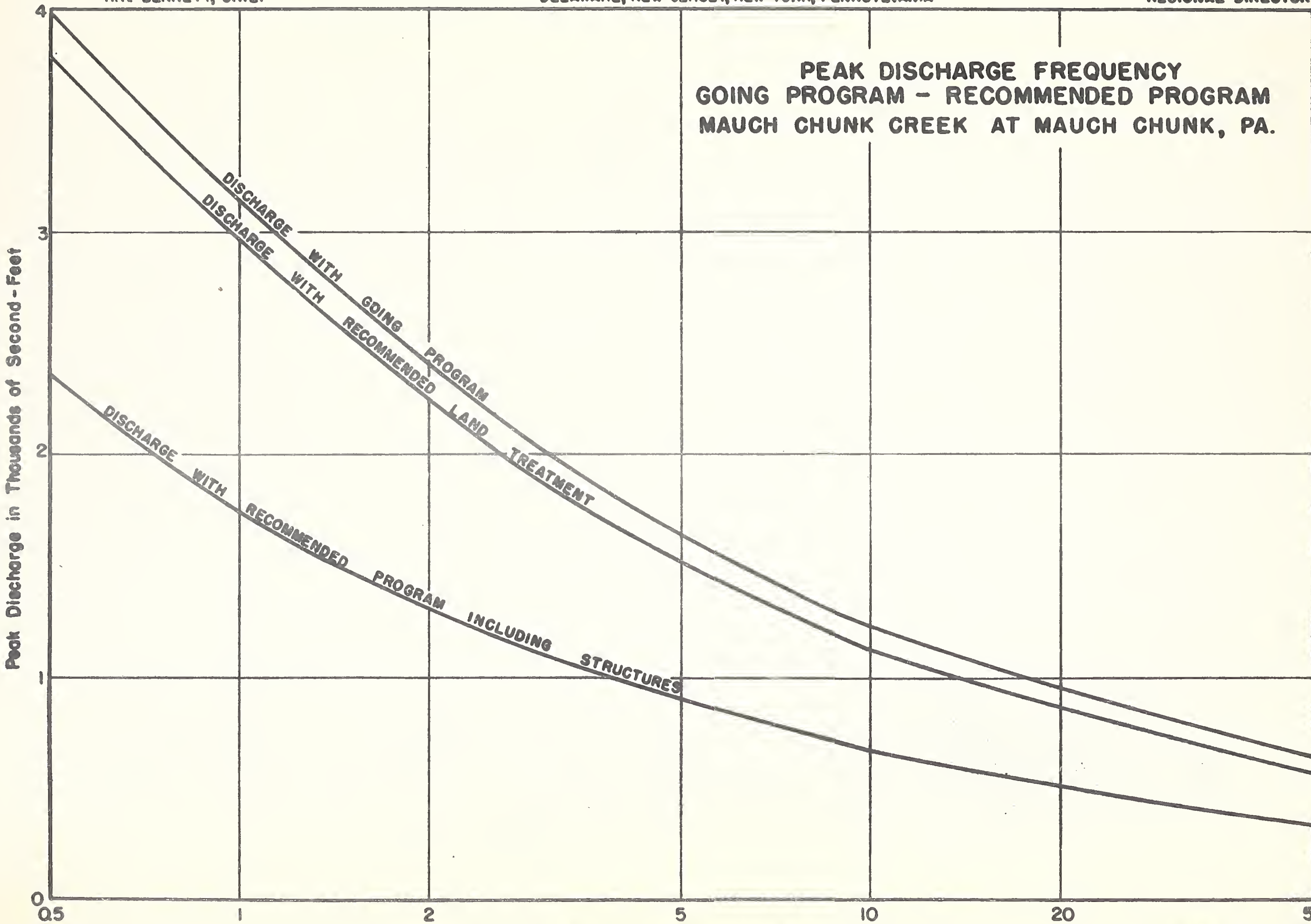

Figure 17.

than its capability would otherwise permit. The flood damage in these areas is relatively low because of the present limited use of the land. However, benefits would be considerable if the frequent flooding were prevented. Based on studies in the sample watersheds and the major tributaries, it was estimated that the value of approximately 19,300 acres of agricultural land would be enhanced by decreasing the frequency of inundation. The enhanced value, in terms of increased annual net income, is approximately $240,000. The benefit is based, in part, on the difference in values of production under present conditions and expected conditions prevailing with the improvement measures installed. About 2,000 acres of the land to be protected are muck land, ordinarily used for truck crops. The value of enhancement on this land was based on annual rent returns. In the muck land area, local opinion strongly favors the installation of the improvement measures. Much of the land subject to enhancement, had been used intensively in the past before the stream channel became clogged with debris and silt.

In all instances where enhancement values were determined no flood damage reductions were claimed. Actually, in computing the amount of enhancement, consideration was given toward increased damage from floods because of more intensive land use. Within practical limits all increased costs of operation due to more intensive land use were, in one case, added to the project cost, and in all other cases deducted from the gross benefit. Costs of clearing, farm ditching, etc., were included in the cost of the improvement.

Reduction in Sediment Damage

Benefits from reduction of sediment damage were computed separately for each classification of damage. Based on erosion control studies, it was estimated that damages caused by sedimentation would be reduced by 60 to 80 percent. The benefits are as follows:

Decreased dredging costs	$448,500
Decreased highway maintenance costs	108,000
Decreased water treatment costs	10,900
TOTAL	$567,400

Conservation Benefits

Benefits of the recommended program other than flood and sediment reductions accrue as a result of the following changes:

1. Decrease in rate of soil erosion.
2. Increased production of crops, forage and woodland products.
3. Savings in farm production costs.

These benefits are a result of the conservation practices and measures recommended for the attainment of reductions in flood and sediment damages.

Decrease in Rate of Soil Erosion

Based on results of soil erosion research, it is expected that the recommended program will reduce the annual soil erosion rates by 80 percent in the Upland section and 75 percent in the Piedmont and Coastal Plain sections. Applying these percentage

reductions directly to the erosion damages shown in Appendix II, the annual cumulative benefits are as follows:

Upland Section	$ 29,400
Piedmont Section	134,000
Coastal Plain Section	13,800

In terms of annual equivalents the benefits in the three sections are $450,000, $920,500, $211,200 respectively, making a watershed total of $1,581,700. The annual equivalent values are based on the assumption of the continuance of the benefits for 50 years in the Upland and Coastal Plain sections and 25 years in the Piedmont section.

Increased Production of Crops, Forage and Woodland Products

Crops - The recommended program includes significant land use adjustments. By these adjustments, the steeper and eroded croplands are converted to other uses such as perennial hay, pasture, or woods, leaving in crops only those lands which can be adequately protected from erosion. Partially off-setting this change is the conversion of some of the less erosive non-cropland to cropping purposes. It is expected that these adjustments along with the application of conservation practices will increase crop yields approximately 15 percent.

The effect of the recommended program on acreage of major crops is shown in table 18. The area of lands shown, include only those which are directly affected by the recommended program. It excludes those which will be treated by going programs, and those which do not excessively contribute to the runoff and erosion problems of the watershed.

Table 18. Recommended Cropland Adjustments
Delaware River Watershed

Watershed Section and Crop	Requiring Treatment or Adjustments	Retired to Non-Crop	Converted to Perennial Hay	Converted from Non-Crop	Future
	(acres)	(acres)	(acres)	(acres)	(acres)
Upland					
Corn	51,200	5,800	5,500	11,100	51,000
Other Row Crops	21,100	2,500	2,300	4,800	21,100
Oats	29,800	3,700	3,600	4,100	26,600
Other Grain	19,700	2,500	2,400	2,700	17,500
Hay	190,400	14,300	-	10,700	200,600
Subtotal	312,200	28,800	13,800	33,400	316,800
Piedmont					
Corn	176,600	17,400	24,100	12,200	147,300
Other Row Crops	57,300	5,600	7,800	3,900	47,800
Oats	75,400	7,400	10,400	3,500	61,100
Other Grain	142,500	14,000	19,700	6,700	115,500
Hay	222,900	32,200	-	48,800	301,500
Subtotal	674,700	76,600	62,000	75,100	673,200
Coastal Plain					
Corn	44,200	12,700	18,400	16,300	29,400
Other Row Crops	16,000	4,600	6,700	5,900	10,600
Oats	800	400	400	300	300
Other Grain	18,200	8,800	9,700	6,900	6,600
Hay	72,600	6,400	-	14,600	116,000
Subtotal	151,800	32,900	35,200	44,000	162,900
Watershed					
Corn	272,000	35,900	48,000	39,600	227,700
Other Row Crops	94,400	12,700	16,800	14,600	79,500
Oats	106,000	11,500	14,400	7,900	88,000
Other Grain	180,400	25,300	31,800	16,300	139,600
Hay	485,900	52,900	-	74,100	618,100
TOTAL	1,138,700	138,300	111,000	152,500	1,152,900

To calculate the benefit from increased value of crop production, the value of present and future production was computed for those lands which would be affected by the recommended program. The value of present production was determined separately for two broad types of cropland, namely, cropland recommended for retirement and cropland to remain in cropland use, but requiring the application of conservation practices and measures. The acreages, production and values of crops in these two categories are shown in tables 19 and 20. Similar data were developed for future production on lands affected by the recommended program and are shown in table 21.

The net result in value of crop production in the watershed is an increase of $9,369,100. For major crops the expected change in value of production is as follows:

Corn	$ 373,000	Increase
Other Row Crops	514,800	"
Oats	53,800	"
Other Grain	447,400	Decrease
Hay	8,874,900	Increase

Pasture - The recommended program will increase production on 685,900 acres of pasture. It is estimated that the carrying capacity of this pasture without the recommended program is 2 acres per grazing unit. Under management conditions, as recommended, it is expected that 1.7 acres will be sufficient for one grazing unit. This is equivalent to an increase of 17.6 percent, or 60,520 grazing animal units. Assuming that the increased carrying capacity applies to 120 days of the grazing season, the increase in number

Table 19. Present Annual Production and Value of Production from Cropland Recommended for Retirement
Delaware River Watershed
(1949 Prices)

Watershed Section and Crop	Acres	Yield Unit	Yield Amount	Total Production	Unit Value (dollars)	Total Value (dollars)
Upland						
Corn	5,800	Bu.	15.0	87,000	1.37	119,200
Other Row Crops	2,500	Bu.	65.0	162,500	1.57	255,100
Oats	3,700	Bu.	15.0	55,500	.78	43,300
Other Grain	2,500	Bu.	10.0	25,000	1.77	44,300
Hay	14,300	Ton	.9	12,900	26.34	339,800
Subtotal	28,800					801,700
Piedmont						
Corn	17,400	Bu.	18.0	313,200	1.33	416,600
Other Row Crops	5,600	Bu.	75.0	420,000	1.37	575,400
Oats	7,400	Bu.	15.0	111,000	.77	85,500
Other Grain	14,000	Bu.	15.0	210,000	1.80	378,000
Hay	32,200	Ton	.9	29,000	26.02	754,600
Subtotal	76,600					2,210,100
Coastal Plain						
Corn	12,700	Bu.	15.0	190,500	1.27	241,900
Other Row Crops	4,600	Bu.	60.0	276,000	1.45	400,200
Oats	400	Bu.	11.0	4,400	.77	3,400
Other Grain	8,800	Bu.	10.0	88,000	1.87	164,600
Hay	6,400	Ton	.9	5,800	25.04	145,200
Subtotal	32,900					955,300
Watershed						
Corn	35,900	Bu.		590,700		777,700
Other Row Crops	12,700	Bu.		858,500		1,230,700
Oats	11,500	Bu.		170,900		132,200
Other Grain	25,300	Bu.		323,000		586,900
Hay	52,900	Ton		47,700		1,239,600
TOTAL	138,300					3,967,100

Table 20. Present Annual Production and Value of Production from Cropland Recommended to Receive Conservation Practices

Delaware River Watershed
(1949 Prices)

Watershed Section and Crop	Acres	Yield Unit	Yield Amount	Total Production	Unit Value	Total Value
					(dollars)	(dollars)
Upland						
Corn	45,400	Bu.	32.0	1,452,800	1.37	1,990,300
Other Row Crops	18,600	Bu.	113.0	2,101,800	1.57	3,299,800
Oats	26,100	Bu.	33.0	861,300	.78	671,800
Other Grain	17,200	Bu.	20.0	344,000	1.77	608,900
Hay	176,100	Ton	1.58	278,200	26.34	7,327,800
Subtotal	283,400					13,898,600
Piedmont						
Corn	159,200	Bu.	33.0	5,253,600	1.33	6,987,300
Other Row Crops	51,700	Bu.	136.0	7,031,200	1.37	9,632,700
Oats	68,000	Bu.	31.0	2,108,000	.77	1,623,200
Other Grain	128,500	Bu.	22.0	2,827,000	1.80	5,088,600
Hay	190,700	Ton	1.40	267,000	26.02	6,947,300
Subtotal	598,100					30,279,100
Coastal Plain						
Corn	31,500	Bu.	33.0	1,039,500	1.27	1,320,200
Other Row Crops	11,400	Bu.	144.0	1,641,600	1.45	2,380,300
Oats	400	Bu.	30.0	12,000	.77	9,200
Other Grain	9,400	Bu.	21.0	197,400	1.87	369,100
Hay	66,200	Ton	1.40	92,700	25.04	2,321,200
Subtotal	118,900					6,400,000
Watershed						
Corn	236,100	Bu.		7,745,900		10,297,800
Other Row Crops	81,700	Bu.		10,774,600		15,312,800
Oats	94,500	Bu.		2,981,300		2,304,200
Other Grain	155,100	Bu.		3,368,400		6,066,600
Hay	433,000	Ton		637,900		16,596,300
TOTAL	1,000,400					50,577,700

Table 21. Future Annual Production and Value of Production of Crops Affected by the Recommended Program
Delaware River Watershed
(1949 Prices)

Watershed Section and Crop	Acres	Yield		Total Production	Unit Value	Total Value
		Unit	Amount			
					(dollars)	(dollars)
Upland						
Corn	51,000	Bu.	37.0	1,887,000	1.37	2,585,200
Other Row Crops	21,100	Bu.	130.0	2,743,000	1.57	4,306,500
Oats	26,600	Bu.	38.0	1,010,800	.78	788,400
Other Grain	17,500	Bu.	23.0	402,500	1.77	712,400
Hay	200,600	Ton	1.80	361,100	26.34	9,511,400
Subtotal	316,800					17,903,900
Piedmont						
Corn	147,300	Bu.	38.0	5,597,400	1.33	7,444,500
Other Row Crops	47,800	Bu.	156.0	7,456,800	1.37	10,215,800
Oats	61,100	Bu.	36.0	2,199,600	.77	1,693,700
Other Grain	115,500	Bu.	25.0	2,887,500	1.80	5,197,500
Hay	301,500	Ton	1.60	482,400	26.02	12,552,000
Subtotal	673,200					37,103,500
Coastal Plain						
Corn	29,400	Bu.	38.0	1,117,200	1.27	1,418,800
Other Row Crops	10,600	Bu.	165.0	1,749,000	1.45	2,536,000
Oats	300	Bu.	35.0	10,500	.77	8,100
Other Grain	6,600	Bu.	24.0	158,400	1.87	296,200
Hay	116,000	Ton	1.60	185,600	25.04	4,647,400
Subtotal	162,900					8,906,500
Watershed						
Corn	227,700	Bu.		8,601,600		11,448,500
Other Row Crops	79,500	Bu.		11,948,800		17,058,300
Oats	88,000	Bu.		3,220,900		2,490,200
Other Grain	139,600	Bu.		3,448,400		6,206,100
Hay	618,100	Ton		1,029,100		26,710,800
TOTAL	1,152,900					63,913,900

of grazing unit days is 7,262,400. Based on the cost of alternate sources of roughage for livestock, the benefit is approximately $3,268,100.

It is expected that the pasture improvement will occur during that portion of the grazing season when forage is usually low. The benefit may accrue as greater production of livestock products or lower feed costs. During those years when pasture production may be in excess of grazing needs, in some instances, the grass may be harvested as hay.

Woodland - Benefits from recommended practices and measures on existing woodland and lands reverting to woodland will occur as a result of increased yields, and a higher proportionate production of the more valuable products. The benefit was calculated as the difference in stumpage value of expected production under conditions with and without the recommended program. Basic data on present and expected growth, kind of products, and stumpage prices were obtained from Forest Service "Reappraisal Reports", Northeastern Forest Experiment Station, state agencies, and from field investigations.

From these data it was estimated that the average annual growth is 29 cubic feet per acre, and the value of this growth under conditions without the recommended program is $1.47. With the program installed, at the time of its maximum effectiveness, the average annual growth per acre is expected to be 79 cubic feet, having a stumpage value of $4.47. The method of deriving cubic foot values for woodland in Pennsylvania is illustrated in table 22.

Table 22. Derivation of Stumpage Values per Cubic Foot of Woodland Growth under Conditions Without and With the Recommended Program in Pennsylvania

Delaware River Watershed)

(1949 prices)

	Unit	Value Per Unit	Without Recommended Program			With Recommended Program	
			Value Per Cubic Foot	Proportion of production	Proportionate value	Proportion of production	Proportionate value
		(dollars)	(dollars)	(percent)	(dollars)	(percent)	(dollars)
Lumber	MBF	12.00	.0600	42.6	.0256	40	.0240
Veneer bolts	MBF	20.00	.1000	0.6	.0006	5	.0050
Pulpwood	Cord	2.00	.0250	4.1	.0010	15	.0038
Fuelwood	Cord	.50	.0071	7.8	.0006	5	.0004
Mine timber	Cord	3.00	.0375	40.0	.0150	15	.0056
Posts	Cord	3.00	.0375	2.1	.0008	5	.0019
Cooperage	Cord	4.00	.0500	-	-	5	.0025
Other	Cord	5.00	.0625	2.8	.0018	10	.0062
Average					.0454		.0494

Conservation benefits are computed for commercial forest land only. Of the present woodland area, approximately 252,300 acres are classified as non-commercial. 1/ An additional 23,700 acres becomes non-commercial as a result of the shrub planting. Future production without the recommended program but including the current program is therefore computed on 3,450,500 acres and future production with the recommended program installed is computed on 3,700,600 acres. The annual value of production without the recommended program will be $785,000 on 175,700 acres of properly managed lands, and $4,814,000 on 3,274,800 acres of unmanaged land, or a total of $5,599,000. The corresponding value with the program installed on 3,700,600 acres will be $16,541,000. The annual benefit is $10,942,000.

Savings in Farm Production Costs

The benefit attained through savings in annual farm production costs was calculated as the net savings resulting from the recommended adjustments in crop acreages. In developing these costs, consideration was given to all significant costs affected by the recommended program except those evaluated as costs of measures and practices shown in table 16 Appendix V. Farm labor requirements, whether obtained by hired labor or family labor, were included as production costs. This inclusion is consistent with the method of developing the costs of recommended practices shown in table 16.

Average per acre costs of crop production on land recommended for retirement were computed at a lower rate than those allowed for lands converted to crops. Because of the higher productivity and economic capacity of the latter lands, production costs were estimated at a higher rate.

1/ Area in state parks, game lands and forest preserves.

The following outline indicates the procedure used in determining the benefit:

1. Conversion of 113,400 acres of row crops to non-cropland and perennial hay; costs decrease at $35 per acre, or $3,969,000.
2. Conversion of 54,200 acres of non-cropland to row crops; costs increase at $65 per acre, or $3,523,000.
3. Conversion of 83,000 acres of grain crops to non-cropland and perennial hay; costs decrease at $15 per acre, or $1,245,000.
4. Conversion of 24,200 acres of non-cropland to grains; costs increase at $30 per acre, or $726,000.
5. Conversion of 52,900 acres of poor hay to non-cropland uses; costs decrease at $13 per acre, or $687,700.
6. Conversion of 96,300 acres of poor hay to perennial hay; costs decrease at $13 per acre, or $1,251,900.
7. Harvesting costs on 96,300 acres of perennial hay (6); costs increase at $6.40 per acre, or $616,300 (only harvesting costs are included because other costs are included in item 5, table 16).
8. Conversion of 185,100 acres of land to perennial hay; costs increase at $6.40 per acre or $1,184,600 (only harvesting costs are included because the other costs are included in item 5, table 16).

9. Increased harvesting costs on 336,700 acres of existing hay lands, requiring protection by conservation practices, and not included in the above acreages due to increased yields; costs increase at $.80 per acre, or $269,400.

The net change in annual production costs, as computed above, is a decrease of $834,300. It should be noted that this decrease in cost is the net change in costs of only those items not included as costs of specific measures shown in table 16. If all costs were analyzed as a group for the watershed cropland, the net result would have been an increase.

Summary of Monetary Benefits

The evaluated monetary benefits attributable to the recommended program are summarized in table 23. These benefits are expected to be attained when the program reaches maximum effectiveness. It is estimated that openland measures will reach maximum effectiveness within five years after installation. The woodland measures are expected to reach 75 percent of maximum effectiveness within 30 years after installation, and attain full effectiveness in 70 years. The additional measures will be fully effective immediately following their installation.

Table 23. Estimated Average Annual Monetary Benefit
from the Recommended Program

Delaware River Watershed
(1949 Prices)

Type of Benefit	Average Annual Benefit	
	(dollars)	
Reduction in damage due to inundation		796,440
Reduction in damages due to sediment:		
Harbor and channel dredging	448,500	
Highways	108,000	
Water treatment	10,900	
Subtotal		567,400
Reduction in damage due to erosion		1,581,700
Land Enhancement		240,000
Other Benefits:		
Increased crop production	9,369,100	
Increased pasture production	3,268,100	
Increased woodland production	10,942,000	
Saving in production costs	834,300	
Subtotal		24,413,500
TOTAL		27,599,040

VII. COMPARISON OF BENEFITS AND COSTS

Benefits and costs were computed separately for the land treatment program, the additional measures, and for the individual groups of measures that are included in the additional measures. All benefits and costs were appraised in terms of 1949 prices. To compare benefits and costs, all values were expressed in annual terms. In converting installation costs to annual values, $2\frac{1}{2}$ and 4 percent interest rates were used respectively for public and private expenditures. For those measures where a significant delay is expected between the time of the expenditure and the accrual of the benefit, discounting was employed using the interest rates cited above. The computed benefit-cost ratios based on prevailing prices in 1949 and under intermediate employment levels during the period 1955-1965 are shown in table 24. The indices used in converting benefits and costs to 1955-1965 price levels are shown in table 26.

Land Treatment Measures and Practices

In developing the land treatment measures, the aim was to include only those measures whose benefits were in excess of costs. However, because of the interdependency of so many of the individual measures and practices, the benefits were developed for the group. The methods of deriving benefits and costs are shown in Appendixes V and VI.

In computing the benefit-cost ratio discounting was employed in evaluating benefits. In the case of woodland measures, certain of the maintenance costs will occur in proportion to the incidence of benefits; therefore they were also discounted.

Table 24. Annual Equivalent of Benefits and Costs of Recommended Program by Groups of Measures
1949 Prices and Alternate Price Level
Delaware River Watershed

Type of Measure	1949 Prices			1955-1965 Prices 1/		
	Annual Cost	Annual Benefit	Benefit Cost Ratio	Annual Cost	Annual Benefit	Benefit Cost Ratio
	(dollars)	(dollars)		(dollars)	(dollars)	
Land Treatment	9,974,691	20,037,388	2.01 to 1	6,541,124	11,656,350	1.78 to 1
Additional Measures:						
Channel Improvement	178,315	620,780	3.48 to 1	121,486	373,958	3.08 to 1
Water Retarding Structures	55,400	134,418	2.43 to 1	37,744	91,579	2.43 to 1
Diking	5,185	10,572	2.04 to 1	3,532	6,368	1.80 to 1
Subtotal	238,900	765,770	3.20 to 1	162,762	471,905	2.90 to 1
All Measures	10,213,591	20,803,158	2.04 to 1	6,703,886	12,128,255	1.81 to 1

1/ Prices expected to prevail under intermediate employment levels in the period 1955-1965.

The land treatment costs and benefits were discounted in the following outline as indicated:

Costs:

Openland (discounting not necessary)

Installation		
Public		
Federal	$23,622,000	
Other Public	858,000	
	$24,480,000	
Annual Equivalent		$ 612,000
Private	$19,773,000	
Annual Equivalent		790,920
Annual Maintenance		
Private		6,938,000
Total Openland Annual Equivalent		$8,340,920

Woodland

Installation (discounting not necessary)		
Public		
Federal	$10,882,000	
Other Public	7,957,000	
	$18,839,000	
Annual Equivalent		$ 470,975
Private	$ 9,759,000	
Annual Equivalent		$ 390,360
Maintenance (Other than tree marking - discounting not necessary)		
Public		
Federal	$ 30,000	
Other Public	46,000	
Private	322,000	
	$ 398,000	
Annual Equivalent		$ 398,000
Tree Marking		
Public		
Federal	$ 252,000	
Other Public	283,000	
	$ 535,000	

Full cost of 535,000 annually after 70 years:	
535,000 x .17755 =	$ 94,989
75% of full cost annually after 30 years for a period of 40 years:	
535,000 x 75% x 25.10278 x .47674 x 2½% =	$ 120,049
Cumulative increase of cost by $\frac{25\% \times 535,000}{40}$ for 40 years, after 30 years:	
3,344 x 433.32478 x .47674 x 2½% =	$ 17,270
Cumulative increase of cost by $\frac{75\% \times 535,000}{30}$ for 30 years:	
13,375 x 286.05078 x 2½% =	$ 95,648
Private $ 95,000	
Full value of cost annually after 70 years:	
95,000 x .06422 =	$ 6,101
75% of full value after 30 years for a period of 40 years:	
95,000 x 75% x 19.79277 x .30832 x 4% =	$ 17,392
Cumulative increase by $\frac{25\% \times 95,000}{40}$ for 40 years after 30 years:	
593.75 x 306.32307 x .30832 x 4% =	$ 2,243
Cumulative increase of cost by $\frac{75\% \times 95,000}{30}$ for 30 years:	
2,375 x 218.35386 x 4% =	$ 20,744
Total Woodland Annual Equivalent of Cost	$ 1,633,771
TOTAL LAND TREATMENT ANNUAL EQUIVALENT OF COST	$ 9,974,691

Benefits:

Reduction in damage due to inundation: $275,650

38% of annual benefit after 5 years:

38% x 275,650 x .88385 =	$	92,581

Cumulative increase of benefit by $\frac{38\% \times 275,650}{5}$ for 5 years:

20,949 x 13.70811 x 2½% =	$	7,179

62% of annual benefit after 70 years:

62% x 275,650 x .17755 =	$	30,344

75% of (62% x 275,650) after 30 years for a period of 40 years:

128,177 x 25.10278 x .47674 x 2½% =	$	38,349

Cumulative increase by $\frac{25\% \ (62\% \times 275,650)}{40}$ for 40 years after 30 years:

1,068 x 433.32478 x .47674 x 2½% =	$	5,516

Cumulative increase by $\frac{75\% \text{ of } (62\% \times 275,650)}{30}$ for 30 years:

4,272 x 286.05078 x 2½% =	$	30,550
Total Annual Equivalent of Benefit	$	204,519

Reduction in damage due to sedimentation: $567,400

Full benefit after 5 years:

567,400 x .88385 =	$	501,496

Cumulative benefit of $\frac{567,400}{5}$ for 5 years:

113,480 x 13.70811 x 2½% =	$	38,890
Total Annual Equivalent of Benefit	$	540,386

Reduction in damage due to erosion: $1,581,700

Full benefit after 5 years:

1,581,700 x .82193 = $ 1,300,047

Cumulative benefit of $\frac{1,581,700}{5}$ for 5 years:

316,340 x 13.00649 x 4% = $ 164,579

Total Annual Equivalent of Benefit $ 1,464,626

Increased Crop Production: $9,369,100

Full benefit after 5 years:

9,369,100 x .82193 = $ 7,700,744

Cumulative benefit of $\frac{9,369,100}{5}$ for 5 years:

1,873,820 x 13.00649 x 4% = $ 974,873

Total Annual Equivalent of Benefit $ 8,675,617

Increased Pasture Production: $3,268,100

Full benefit after 5 years:

3,268,100 x .82193 = $ 2,686,149

Cumulative benefit of $\frac{3,268,100}{5}$ for 5 years:

653,620 x 13.00649 x 4% = $ 340,052

Total Annual Equivalent of Benefit $ 3,026,201

Savings in Production Costs: $834,300

Full benefit after 5 years:

834,300 x .82193 = $ 685,736

Cumulative benefit of $\frac{834,300}{5}$ for 5 years:

166,860 x 13.00649 x 4% = $ 86,810

Total Annual Equivalent of Benefit $ 772,546

Increased Woodland Production: $10,942,000

Full benefit after 70 years:

10,942,000 x .06422 =	$ 702,695

75% of full benefit after 30 years for a period of 40 years:

8,206,500 x 19.79277 x .30832 x 4% =	$ 2,003,209

Annual cumulative increase of benefit by $\frac{25\% \times 10,942,000}{40}$ for 40 years after 30 years:

68,389 x 306.32307 x .30832 x 4% =	$ 258,361

Annual cumulative increase of benefit by $\frac{75\% \times 10,942,000}{30}$ for 30 years:

273,550 x 218.35386 x 4% =	$ 2,389,228
Total Woodland Production Benefit	$ 5,353,493
TOTAL LAND TREATMENT BENEFIT	$20,037,388

Additional Measures

In determining the additional measures to be recommended, each specific measure was evaluated to determine its cost and benefit. The annual equivalents of costs and benefits and the benefit-cost ratios of additional measures are shown in table 25.

The benefit-cost ratios for water retarding structures, in some cases, include more than one structure. However, the incremental benefit of each additional structure was at least equal to the incremental cost. In computing the benefits attributable to water retarding structures account was taken of the additional benefit because of the time lag between installation and maximum benefit accrual of the land treatment measures. It will be noted

Table 25

ADDITIONAL MEASURES ---- ANNUAL EQUIVALENT COST AND BENEFIT ---- BENEFIT-COST RATIO
1949 and 1955-65 Prices

Type of Measure and Location	No.	1949 Prices: Annual Equivalent Costs (Dollars)	1949 Prices: Annual Equivalent Benefit (Dollars)	1949 Prices: Benefit Cost Ratio	1955-1965 Prices: Annual Equivalent Costs (Dollars)	1955-1965 Prices: Annual Equivalent Benefit (Dollars)	1955-1965 Prices: Benefit Cost Ratio
Stream Channel Improvement							
Pequest		59440	371200	6.24-1	40496	223611	5.52-1
Pohopoco and Mahoning		14296	32850	2.30-1	9740	19789	2.03-1
Sample Watershed No. 53		57	108	1.89-1	39	65	1.67-1
No. 63		39	58	1.49-1	27	35	1.30-1
No. 92		145	148	1.02-1	99	89	.90-1
No. 62		146	191	1.31-1	99	115	1.16-1
No.109		70	380	5.43-1	48	229	4.77-1
No.114		37	147	3.97-1	25	89	3.56-1
No.456		2082	2329	1.12-1	1418	1403	.99-1
No.160		14	18	1.29-1	10	11	1.10-1
No.492		787	3630	4.61-1	536	2187	4.08-1
No. 72		53	59	1.11-1	36	36	1.00-1
Water Retarding Structures							
Little Beaver Kill	8	1904	3276	1.72-1	1297	2232	1.72-1
Bushkill Creek	9	2485	10528	4.24-1	1693	7173	4.24-1
Saucon	4	952	902	.95-1	649	615	.95-1
Monocacy	6	1428	8067	5.65-1	973	5496	5.65-1
Catasauqua	4	952	1440	1.51-1	649	981	1.51-1
Hokendauqua	6	1428	1574	1.10-1	973	1072	1.10-1
Aquashicola	5	15093	23157	1.53-1	10283	15777	1.53-1
Mauch Chunk	1	7004	8385	1.20-1	4772	5713	1.20-1

Table 25
(continued)

Additional Measures ---- Annual Equivalent Cost and Benefit ---- Benefit-Cost Ratio
1949 and 1955-65 Prices

Type of Measure and Location	No.	1949 Prices			1955-1965 Prices		
		Annual Equivalent Costs (Dollars)	Annual Equivalent Benefit (Dollars)	Benefit Cost Ratio	Annual Equivalent Costs (Dollars)	Annual Equivalent Benefit (Dollars)	Benefit Cost Ratio
Water Retarding Structures (cont.)							
Lopatcong	6	1428	8398	5.88-1	973	5722	5.88-1
Chester Creek	7	1666	5913	3.55-1	1135	4029	3.55-1
Red Clay Creek	2	476	1435	3.01-1	324	978	3.01-1
Sample Watershed No. 53	1	219	236	1.08-1	149	161	1.08-1
No. 244	1	238	250	1.05-1	162	170	1.05-1
No. 492	1	335	1560	4.66-1	228	1063	4.66-1
Diking							
Jordan		3426	5330	1.56-1	2334	3211	1.38-1
Mahoning		428	1560	3.64-1	292	940	3.22-1
Sample Watershed No. 53		42	46	1.10-1	29	28	.97-1
No. 49		99	128	1.29-1	67	77	1.15-1
No. 109		11	17	1.55-1	7	10	1.43-1
No. 221		5	20	4.00-1	3	12	4.00-1

that one structure has a benefit-cost ratio of .95-1. Since all of the structures of this type will have a conservation pool, there will be on-site benefits in addition to the evaluated flood reduction benefits. Depending upon the location of the structure and its ownership, the conservation pool may provide water for farm needs, fire control, recreation and other purposes. It is considered that the unevaluated on-site benefits will be sufficiently large to produce a favorable benefit-cost ratio.

The benefit-cost ratios based on 1955-1965 prices are less than 1.0 to 1 for stream channel improvement in sample watersheds 92 and 456, and for diking in sample watershed 53. Based on 1949 prices, however, each of these improvements indicate a favorable benefit-cost ratio. It will be noted in table 26, that the index of "prices received by farmers" was used in converting benefits attributable to channel improvement and diking from 1949 to 1955-1965 prices. This index was used because, in general, most of the benefits from such improvements are reduction in flood damage to growing crops and agricultural land enhancement. However, the benefits in sample watersheds 92 and 53 are mainly reductions in flood damage to highways and bridges, therefore the index of "construction cost" would be more applicable in converting benefits from 1949 prices to 1955-1965 prices for these two sample watersheds. Using this index, the benefits based on the latter prices would have been reduced 31.87 percent instead of 39.76 percent, leaving a favorable benefit-cost ratio.

In the case of sample watershed 456, most of the benefits will accrue as enhancement of poor pasture land. This benefit, is therefore, dependent upon the production of dairy products, and if the index of "prices received by farmers for dairy products" were used, the reduction of benefits in converting from 1949 prices to 1955-1965 prices would have been 36.255 percent instead of 39.76, thus creating a favorable benefit-cost ratio.

The annual equivalents of costs and benefits of the three groups of additional measures were developed as follows:

Channel Improvement

Costs:		
Installation:		
Federal	$2,260,000	
Other Public	183,000	
Total	$2,443,000	
Annual Equivalent		$ 61,075
Private	$ 381,000	
Annual Equivalent		$ 15,240
Maintenance:		
Other Public	$ 44,000	
Private	58,000	
Total	$ 102,000	
Annual Equivalent		$ 102,000
TOTAL ANNUAL EQUIVALENT COST		$ 178,315
Benefits:		
Flood Damage Reduction	$ 380,780	
Land Enhancement	240,000	
Total	$ 620,780	
Annual Equivalent		$ 620,780

Floodwater Retarding Structures

Costs:		
Installation:		
Federal	$1,071,000	
Other Public	217,000	
Total	$1,288,000	
Annual Equivalent		$ 32,200
Private	$ 55,000	
Annual Equivalent		$ 2,200
Maintenance:		
Other Public	$ 20,000	
Private	1,000	
Total	$ 21,000	
Annual Equivalent		$ 21,000
TOTAL ANNUAL EQUIVALENT		$ 55,400
Benefits:		
Flood Damage Reductions	$ 134,418 1/	
Annual Equivalent		$ 134,418

Diking

Costs:		
Installation:		
Federal	$ 69,000	
Other Public	4,000	
Total	$ 73,000	
Annual Equivalent		$ 1,825

1/ Includes $4,980 to account for the additional benefit attributable to flood water retarding structures because of the time lag between installation and maximum benefit accrual of the land treatment measures. This value is not shown in table 17.

Private	$ 9,000	
Annual Equivalent		$ 360
Maintenance:		
Other Public	$ 2,000	
Private	1,000	
Total	$ 3,000	
Annual Equivalent		$ 3,000
TOTAL ANNUAL EQUIVALENT		$ 5,185
Benefits:		
Flood Damage Reduction	$10,572	
Annual Equivalent		$10,572

Conversion of 1949 Prices and Costs to 1955-1965 Levels

To convert the benefits and costs calculated in terms of 1949 prices and costs to those expected to prevail during the period 1955-1965 the indices shown in table 26 were used.

Table 26. Indices Used in Converting Costs and Benefits to Price and Cost Levels of 1955-1965 1/
Delaware River Watershed

Name of Index	Index Number		Item of Cost or Benefit
	1949	1955-1965	
Prices received by farmers 2/	249	150	Reduction of flood damage by dikes and channel improvement
			Land enhancement
			Reduction in erosion damage
			Increased crop production
			Increased pasture production
Prices paid by farmers 2/	238	155	Savings in production costs
			Private costs of land treatment
Wholesale lumber prices 3/	286	145	Increased woodland production
Construction cost 4/	477	325	Reduction of flood damages by land treatment and water retarding structures
			Reduction in sediment damage
			All other costs

1/ Under condition of intermediate employment.
2/ Bureau of Agricultural Economics.
3/ U. S. Department of Labor.
4/ Engineering News Record.